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APPLIED MECHANICS REVIEWS

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HIGH TEMPERATURE EFFECTS IN AIRCRAFT STRUCTURES

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AERODYNAMIC HEATING

WHEN an airplane or a guided missile is flying at a supersonic speed, its surface is heated by the air flow. This heating is a consequence of the fact that the air adheres to the surface of the structure. The relative velocity of aircraft and air is zero at the surface, and the high kinetic energy of the average relative velocity of flight is transformed into the kinetic energy of the random motion of the molecules of which air is composed. This increased agitation of the molecules of air manifests itself as an elevated temperature.

The relative velocity of the flow increases rapidly from the surface of the aircraft in a direction perpendicular to the surface; it reaches its full value at a small distance from the surface. This small distance is designated as the thickness of the boundary layer. As the air is at an elevated temperature near the surface of the airplane or missile, it transfers heat to the structure. At the same time some heat is also transferred through the boundary layer in the opposite direction, i.e., away from the structure. Thus aerodynamic heating is a rather complex phenomenon and, even though a great deal of experimental and theoretical effort has been made to clarify it, a complete understanding of it is available today only for the simplest patterns of flow. The most important single fact about aerodynamic heating is that it increases approximately as the square of the flight velocity. Good summaries of the formulas and of the values of the physical constants involved have been presented by Eckert (1)[1] and Bloom (2).

To give an appreciation of the magnitude of the energy involved in aerodynamic heating, a few numerical values will be quoted. In 1946, Wood (3) calculated the heating rates for aircraft flying at various elevations at different speeds. He found that at an elevation of 50,000 ft the heating rate was 30 Btu per sq ft per sec when the velocity of the aircraft corresponded to a Mach number of 4, and it was 450 Btu per sq ft per sec at a Mach number of 10. These values were obtained at a distance of 1 ft from the leading edge of the wing on the assumption that the temperature of the structure was 460° F. The meaning of such heating rates can be appreciated if one remembers that 1 Btu per sec is equivalent to 1.055 kilowatts or to 1.42 horsepower. In 1955, McLellan (4) presented data on the heating rates anticipated with guided missiles. He assumed a range of 3450 miles for a ballistic missile. He found that such a missile would have to reach a maximum elevation of 650 miles above the surface of the earth in order to fulfill its mission. At such an elevation the air is so thin that the aerodynamic heating effect is negligible. However, when the missile re-enters the thicker layer of air near the surface of the earth, the high velocity combined with the high density gives rise to extremely high rates of heating. McLellan calculated a heating rate of 10,000 Btu per sq ft per sec for a turbulent boundary layer. He stated also that this heating rate was about 1000 times the rate used in standard boilers.

In a discussion of the structural effects of aerodynamic heating, distinction should be made between the effects of moderate heating extending over long periods of time and those of rapid heating occurring only for short time intervals. The former arise at low supersonic speeds of military or civilian airplanes. Such speeds will undoubtedly be maintained for several hours repeatedly as soon as nuclear engines are installed in airplanes. Very violent heating can occur for a few seconds or at the most for a few minutes in missiles of all kinds. The considerations of structural design and analysis are naturally entirely different for these two groups of problems.

The various problems involved can probably be discussed best under the following four headings:

1. Reduction of strength and stiffness at moderate temperatures.
2. Thermal stresses and thermal buckling.
3. Effects of creep on stress distribution and failure.
4. Creep buckling.

Many of these problems have been described in some detail in (5) to (13).

The literature of aerodynamic heating, material properties at high temperatures, thermal stresses, and creep is so extensive that it would be easy to quote well over a thousand relevant articles. The only procedure the writer could follow without exceeding his space limitations was therefore to select, somewhat at random, a small number of representative articles on the subjects. In this process many worth-while papers naturally had to be omitted.

REDUCTION OF STRENGTH AND STIFFNESS AT MODERATE TEMPERATURES

This group of problems is of the greatest immediate interest to

[1] Numbers in parentheses indicate References at end of paper.

airplane designers today. At the same time it offers the easiest means to obtain design information. No new analytical or design principles need be introduced and the concepts of safety generally accepted for subsonic aircraft can be maintained essentially unchanged. As the temperature rises, the elastic limit, the yield point, and the ultimate strength of the metals used in aircraft structures decrease. If the usual static tests are carried out with aircraft materials at all the elevated temperatures of interest, the data so obtained can be used in structural design in the same manner as room temperature data have been used for the design of our present transport planes. It has also been shown that the buckling loads of columns can be calculated with sufficient accuracy with the aid of the tangent modulus values pertaining to elevated temperatures. Material data of this kind have been gathered in many research laboratories and information on them can be found in (5) to (13). A comparison of the structural efficiency of various structural materials at elevated temperatures was given by Heimerl and Hughes in (14). The problem of fatigue under thermal stresses was investigated by Coffin (15).

THERMAL STRESSES AND THERMAL BUCKLING

When a structure is heated nonuniformly, it cannot in general expand freely because its natural expansion corresponding to an arbitrarily prescribed temperature distribution would be possible only if cracks developed in the material of the structure. The continuity of the structure is preserved by internal stresses developing in the structure; these stresses are known as thermal stresses. The analysis of thermal stresses has a long history; probably the first paper in this field was published by Duhamel (16) in 1838. A recent book dealing exclusively with thermal stresses was written by Melan and Parkus (17) in 1953. Publications on thermal stresses are listed under (18) to (24).

As the thermal stresses are caused by the incompatibility of the thermal deformations, the stresses cannot reach very large values if the material is capable of large inelastic deformations under moderately large stresses. This is true of most structures when the temperature of the material is raised; on the other hand, cracks may easily develop under thermal stresses when a structure is nonuniformly cooled. The behavior of materials under thermal stresses was investigated by Manson (25). At high temperatures thermal stresses are further alleviated by creep. In this regard, a paper by Hilton and others (26) may be mentioned here; creep effects will be discussed in more detail later.

A great deal of experimental information is available to show that thin, flat structural elements buckle and become wavy under comparatively small thermal stresses. It seems therefore that the greatest objection to the development of thermal stresses is the reduction in rigidity and the unevenness of the surface of the aircraft structure resulting from thermal buckling. The unevenness of the surface and the reduction in torsional rigidity may cause flutter, as was described in (12). The only theoretical paper dealing with thermal buckling, as far as is known to the writer, is one by Gossard, Seide, and Roberts (27). Further work on this subject is now in progress in various research organizations.

EFFECTS OF CREEP ON STRESS DISTRIBUTION AND FAILURE

A solid is said to creep if it changes its shape continuously with time when subjected to unchanging loads. If a weight is suspended from a lead wire, the length of the wire increases with time under the constant load. On the other hand, structural steels and aluminum alloys do not show any marked creep at room temperatures; this is, of course, one of the reasons why they are used as structural materials. But at the temperatures to which supersonic aircraft is subjected, every known metal experiences a considerable amount of creep. For this reason it is of great importance to the structural designer of supersonic aircraft to learn more about the creep phenomenon.

The first man to investigate creep in some detail was Andrade (28) who, in his fundamental paper published in 1910, disclosed most of the important features of creep in metals. More recent summaries of our knowledge of the creep phenomenon are given in (29) to (34).

Most structural engineers do not quite realize that creep not only is responsible for continuing permanent deformations but also causes radical changes in the stress distribution. No real structure is truly statically determinate and all the structural elements used in aircraft are highly redundant. While in a statically determinate structure the stresses can be calculated on the basis of the conditions of equilibrium alone, in a redundant structure the stress distribution is influenced also by the deformations of the structural elements. These deformations, of course, depend very much on the law connecting the stresses with the strains, and the law is usually entirely different in the presence of creep from Hooke's law governing the deformations of perfectly elastic materials. The many stress-strain rate laws proposed by various investigators to describe the creep phenomenon will not be discussed here in detail because they were reviewed recently in APPLIED MECHANICS REVIEWS by Odqvist (35). Other summaries of creep laws can be found in (36) and (37).

When the temperatures are steady and moderately high and the loads are applied for many hours, the long-range effects of creep become important. These effects were analyzed in the 1930's by Bailey (38), Odqvist (39, 40), and Soderberg (41). One of the interesting results of such analyses can be found in (41). If the nut on a bolt connecting two parts of a steam engine is tightened by a workman, elastic stresses are developed in the bolt. These stresses are necessary to maintain a firm connection between the two parts and to prevent the loosening of the nut in consequence of vibrations. If the bolt is at a high temperature, creep sets in and the creep deformations decrease the initial stress introduced by the workman. After a sufficiently long time the bolt becomes loose. This important phenomenon was completely explained by Soderberg in (41).

The laws describing the long-range effects of the creep phenomenon must often be discarded and replaced by different laws when creep takes place as rapidly as it does in guided missile structures. When a missile has to fly only for ten seconds or perhaps for ten minutes before it hits the attacking enemy missile or bomber plane, creep rates of several per cent per hour are perfectly permissible because they cannot lead to large enough deformations to interfere with the proper functioning of the structure in the short lifetime of the missile. These values should be compared with the creep rates considered permissible in heat power machinery in the 1930's; they were of the order of magnitude of a few hundredths of a per cent in 10,000 hr. Some of the considerations pertinent to this rapid creep are described in (42) to (45).

When the material, its heat treatment, its cold working, the stresses applied, the duration of the loading, and the temperature are such that the secondary phase of creep is the one making the significant contribution to the creep deformations, the stress analysis can be greatly simplified by means of the elastic analog described in (43). According to this analog the stress distribution in a body subjected to secondary creep deformations alone is the same as the stress distribution in a perfectly elastic body, provided the stress-strain law of the elastic body is related to the stress-strain rate law of the body that creeps in a certain simple manner. Thus the problem of analyzing the stress distribution in the presence of creep is reduced to the analysis of the stresses in a perfectly elastic body. Unfortunately the stress-strain law

of this perfectly elastic body is a highly nonlinear one and, for this reason, the analysis of the stresses, although perfectly possible in principle, presents great practical and numerical difficulties. In many cases a somewhat simpler, although approximate, analysis is possible if use is made of the plastic analog described in some detail in (45). Then the calculations can be carried out by the relatively simple methods of limit analysis.

Very often, however, the various parameters influencing creep appear in such combinations that either the elastic deformations or the primary creep deformations must also be taken into account. Whenever this occurs, the analysis becomes much more involved.

Another effect that has to be mentioned in this connection is failure in consequence of creep deformations. It was already observed by Andrade that wires subjected to tensile loads failed when their cross-sectional area was reduced sufficiently in consequence of creep so that under the constant load the failing stress of the material at the particular temperature was reached. The analysis presented in (46) shows how the time at which rupture occurs can be calculated from the creep strain rate law.

This phenomenon introduces a new concept into structural analysis. As every bar subjected to tension fails eventually if the tensile load, however small, is permitted to act on it for a sufficiently long time, one can no longer speak of safe loads, but only of safe periods of loading. In other words, the concept of a safe or permissible load has to be replaced by the concept of the critical time or of a permissible duration of loading. If the load is allowed to act on the body for a time interval exceeding the critical time, the structure is bound to fail by fracture. In general, this critical time can be increased considerably by reducing only slightly the stresses acting on the body.

CREEP BUCKLING

A similar time effect is observed with structural elements in compression. When a pin-ended column is subjected to an axial compressive load, the center line of the column and the straight line connecting the two pin ends along which the axial compressive load is acting do not exactly coincide because of the inaccuracies of workmanship and of the alignment of the column in the testing machine or in the structure. The small deviations of the center line from the line of action of the force constitute lever arms which, when multiplied by the compressive load, become the bending moments to which the particular sections of the column are subjected. Under these bending moments the curvature of the column increases in consequence of creep. This means in turn that the initial deviations of the center line from the line of action of the load increase with time. When the creep rate increases as a relatively high power of the stress, as is usual with structural metals at elevated temperatures, the creep deformations increase slowly at the beginning of the loading but are accelerated later until, in the neighborhood of the critical time, the acceleration reaches such values that the column is observed to snap through suddenly and to fail. Such a behavior pattern has been obtained analytically and has also been observed in experiment. Thus it can be stated that a critical time exists for every column at which the column buckles, even though earlier it appeared to be perfectly capable of supporting the compressive load. The critical time is influenced very much by the average stress acting on the column and to a lesser extent by the initial deviations of the center line of the column from the line of action of the compressive load. Of course the critical time also depends on the material properties and, for this reason, on the material itself and on the temperature at which the loading takes place. It is important to realize, however, that every column will fail eventually no matter how small the compressive load acting on it if the load is applied to the column for a sufficiently long period of time. For this reason there is no safe compressive load for the column either; one can talk only of a safe period of time of load application.

As far as is known, the first analytical study of creep buckling was carried out by Freudenthal (47) who presented his results at the Sixth International Congress of Applied Mechanics in Paris, France, in 1946. Because of the importance of creep buckling to the safety of aircraft structures, many investigators have contributed to the theory and practice of column buckling since that time. A list of some of these contributions can be found in (48) to (61).

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58 Mathauser, E. E., and Brooks, W. A., Jr., An investigation of the creep lifetime of 75S-T6 aluminum-alloy columns, *NACA TN* 3204, July 1954; AMR **7**, Rev. 3876.

59 Odqvist, F. K. G., Influence of primary creep on column buckling, *J. appl. Mech.* **21**, 3, p. 295, Sept. 1954; AMR 8, Rev. 1002.

60 Hoff, N. J., Creep buckling, *PIBAL Rep.* no. 252, Polytechnic Institute of Brooklyn, May 1954; also to be published in *Aeronautical Quarterly*, Nov. 1955.

61 Patel, S. A., Buckling of columns in the presence of creep, *PIBAL Rep.* no. 292, Polytechnic Institute of Brooklyn, May 1955; also to be published in *Aeronautical Quarterly*, February 1956.

Books Received for Review

BIRKHOFF, G., Hydrodynamics, a study in logic, fact and similitude, New York, Dover Publications, Inc., 1955, xiii + 186 pp. $1.75 (paperbound), $3.50 (clothbound).

BLACK, P. H., Machine design, 2nd ed., New York, Toronto, London, McGraw-Hill Book Co., Inc., 1955, viii + 471 pp. $7.50.

BONOLA, R., Non-Euclidean geometry, New York, Dover Publications, Inc., 1955, xii + 268 pp. $1.90 (paperbound), $3.95 (clothbound). (Supplement contains two papers: The science of absolute space, by John Bolyai; and The theory of parallels, by Nicholas Lobachevski.)

BRUN, E. A., Introduction à l'Étude de la Couche Limite, Paris, Gauthier-Villars, 1955, 189 pp. $5.28 (paperbound).

COLONNETTI, G., L'Equilibre des corps deformables, Paris, Dunod, 1955, xi + 162 pp. 1680 Fr.

DUKE, N., AND LANCHBERY, E., Sound barrier, the story of high-speed flight, New York, Philosophical Library, Inc., 1955, xi + 129 pp. $4.75.

FORBES, G. F., Digital differential analyzers, Part I, The elements, Pacoima, California, George F. Forbes, 1955, v + 54 pp. $7.50 (paperbound).

HAAG, J., Les mouvements vibratoires, Vol. II, Paris, Presses Universitaires de France, 1955, viii + 253 pp. (Paperbound).

HORNER, J. G., Dictionary of mechanical engineering terms, 7th ed., Rev. by Staton Abbey, New York, Philosophical Library, Inc., 1955, iv + 417 pp. $6.50.

MINER, D. F., AND SEASTONE, J. B., editors, Handbook of engineering materials, 1st ed., New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1955, xi + 1480 pp. $17.50.

MORRIS, J. L., Modern manufacturing processes, New York, Prentice-Hall, Inc., 1955, ix + 533 pp. $9.35.

POLACZEK, K., Getriebelehre eine Einführung, Munich, Carl Hanser Verlag, 1955, 56 pp. DM 4.80 (paperbound).

POWELL, C. F., CAMPBELL, I. E., AND GONSER, B. W., Vapor-plating, the formation of metallic and refractory coatings by vapor deposition, New York, John Wiley & Sons, Inc., 1955, vi + 158 pp. $5.50.

PRAGER, W., Probleme der Plastizitatstheorie, Basel, Stuttgart, Birkhauser Verlag, 1955, 100 pp. DM 12.50.

RUMFORD, F., Chemical engineering materials, New York, Chemical Publishing Co. Inc., 1955, x + 382 pp. $7.50.

STARKEY, B. J., Laplace transforms for electrical engineers, New York, Philosophical Library; London, Iliffe & Sons, Ltd., 1955, 279 pp. $10.

THALER, G. J., Elements of servomechanism theory, New York, Toronto, London, McGraw-Hill Book Co., Inc., 1955, x + 282 pp. $7.50.

Letters to the Editor

3263. Re AMR 8, Rev. 162 (January 1955): R. W. Truitt, Solution of the general two-dimensional subsonic compressible flow by a new physical transformation.

Reviewer claims priority over subject paper by citing his paper (*NACA RM* no. A7B10, May 1947), the contents of which have no relation whatever to the subject paper's derivation of a new relativistic physical transformation for subsonic compressible flow. The subject paper is a continuation of an original development, by R. W. Truitt, of a new relativistic sound-space theory [AMR **4,** Rev. 4528] which was developed from the analogy of the special theory of relativity to the study of compressible fluid flow [AMR **3,** Rev. 2005].

The reviewer further cites his own paper [AMR **5,** Rev. 1805], which was written apparently in an attempt to justify his earlier claim to priority, when the reviewer thought (erroneously) that he had discovered a new compressibility correction [AMR **4,** Rev. 4526]; the proof of Truitt's priority in this case was given by V. G. Szebehely [AMR **5,** Rev. 1806].

The reviewer states that the subject paper ". . . .is only applicable to small perturbations, because velocity of sound must be assumed constant in his development." The reviewer obviously missed the most important and fundamental part of the paper; the paper states: . . ."These time and space-unit transformations defined on the local velocity of sound are, in fact, a point-to-point transformation. . .". It is clear that, under the assumption of steady flow, the *local* velocity of sound *is* constant at any given *point* in the flow field. The application of the relativistic *point-to-point* transformation does *not* require, therefore, that the velocity of sound be assumed constant throughout the flow field, but only at the *local point* under consideration.

The reviewer states that the author (Truitt) is wrong in stating that his new compressibility correction includes nonlinear effects. It is very easy to show that the relativistic sound-space compressibility correction, which involves the local Mach number, *does,* in fact, include nonlinear effects; the fact that the use of local Mach number results in nonlinear effects has been established by J. D. Cole (Air Force Technical Note, OSR-TN 228, May 1954) and R. W. Truitt (Air Force Technical Report, OSR-TR-55-14, May 1955). It is strange, indeed, that the reviewer, in one paragraph, denies the existence of nonlinear effects in the sound-space compressibility correction, and, in the next paragraph, reverses himself completely, by stating that the use of local Mach number does include nonlinear effects.

R. Truitt, USA

Theoretical and Experimental Methods

(See also Revs. 3288, 3297, 3304, 3305, 3306, 3321, 3329, 3335, 3349, 3362, 3370, 3379, 3380, 3451, 3459, 3480, 3508, 3532, 3545, 3564)

3264. Baule, B., Mathematics for naturalists and engineers. Vol. I. Differential and integral calculus [Die Mathematik des Naturforschers und Ingenieurs. Bd. I. Differential- und Integralrechnung], 9th ed., Leipzig, S. Hirzel Verlag, 1954, viii + 187 pp., 183 figs. DM 7 (paperbound).

In this book there are treated functions of one and several variables, differential and integral calculus and their application to the geometry of plane curves. It contains an abundant collection of examples computed in detail and clearly annotated by remarks in which the difficulties of each problem are referred to. The theoretical part of the book is not uniformly treated. Some theorems are strictly developed and demonstrated, some only by geometric imagination, several quoted without demonstration, several are missing, so that a reader not acquainted with the matter of the book cannot see how one theorem is logically developed from the other. Some demonstrations and developments could be more simplified. Containing so many good exercises computed in detail, the book is very well adapted to students interested in the practice of the calculus.

J. Lense, Germany

3265. Morse, P. M., and Feshbach, H., Methods of theoretical physics, Parts I, II (International Series in Pure and Applied Physics), New York, Toronto, London, McGraw-Hill Book Co., Inc., 1953, xii + 1037 pp.; xviii + 980 pp.

This treatise on the solution of partial differential and integral equations has become a standard reference for many workers in the field of applied mathematics and theoretical physics. Contained in two volumes, the book is clearly written and has stereoscopic projections to illustrate spatial concepts discussed in the text. The amount of material covered in these two books would make it impractical to give a detailed review of all of the chapters. A prerequisite for one desiring to obtain knowledge of the material treated is a course in advanced calculus. The authors present vector operations very nicely in the first chapter but do rely quite heavily on the student's ability to handle partial differentiation.

It is unfortunate that, in the treatment of curvilinear coordinates, generalized formulas were not included and that the authors restricted themselves to orthogonal systems only. The symmetry that is associated with the metric coefficients in generalized coordinates is lost, requiring the authors to "spell out" otherwise compact results. The use of diadics in connection with the theory of deformable bodies is well presented and is typical of the method used to derive the equations of mathematical physics from the physical principles. These equations are then treated from the point of view of solving the mathematical equations, retaining excellent coherence between the different physical systems possessing the same mathematical formulation. The concept of the total derivative in connection with fluid motion is neatly expressed and easily understood. It is typical of authors' attempt to eliminate detailed mathematical rigor and give only the essence of the formulation. The third chapter treats the variational principles and the conversion of differential equations into variational form. The completeness of the mathematical tools presented in these books is to be commended. However, in obtaining this completeness, the elaboration on any one subject has had to be kept at a minimum. In many cases, this will require the reader who is not well versed in the many subtleties to find self-study taxing.

The authors include the very often unmentioned subject of separable coordinate systems. The particular higher functions of mathematical physics which arise from the separated differen-

tial equations are treated and their properties listed. The concepts of a Green's function and its relation to integral equations and transform methods are given.

The second volume of the series starts off with approximate methods which include perturbation analysis and variational methods for the determination of eigenvalues. Chapters 10, 11, and 12 treat the common equation in great detail with a broad coverage of the physical systems yielding Laplace, Poisson, the wave, and diffusion equations. All of these involve a single function of boundary-value problem. The last chapter in this book treats vector boundary conditions and is exemplified by calculations showing the viscous flow about a sphere and reflections of elastic waves at boundaries. Again, the completeness of the physical subjects treated is indicative of the careful thought the authors have put into this book.

At the end of each chapter there is a bibliography which is broken down into two categories; general reference for material covered in the chapter and then specific references on the subjects discussed in the chapter. Of particular value is a summary, at the end of chap. 5, of the separable coordinate systems in three space. Here the use of the stereographic projection is very helpful; however, reviewer found it necessary to use a stereoviewer to obtain their fullest value. Much of the material in these two volumes has not been unified in a book. In fact, some has only been available in the journals.

This work is highly recommended to students and research workers in the fields connected with applied mathematics and theoretical physics. S. L. Levy, USA

3266. Petrovskiĭ, I. G., Lectures on the theory of ordinary differential equations [Lektsiĭ po teoriĭ obyknovennikh differentsialnikh uravneniĭ], 4th ed., Moscow-Leningrad, Gos. Izdat. Tekh.-Teor. Lit., 1952, 232 pp.

Volume in question is a revised and completely new edition of the well-known textbook designed for students of physico-mathematical faculties of the Russian universities. The most substantial supplement to previous editions consists in the paragraph on Chaplígin's differential inequalities, which are of importance in approximating unknown solutions of differential equations. There have been added many new problems, enlarging the subject, and also numerous examples suitable for research work in mathematical seminaries.

Content is divided into two main parts on ordinary equations and an appendix on partial differential equations.

The first section is divided into three chapters with 27 subsections and constitutes an essential foundation of a first course in differential equations. Author does not explain all elementary ways and artificial devices applied in solving special types of equations. Rather, he has chosen several typical problems and these are discussed with much more accuracy than is customary in elementary textbooks on differential equations.

The following few facts may give an idea of the high standards in presenting the subject: Existence theorem for the equation $y' = f(x,y)$ is proved by Peano's method with the aid of Arzela's theorem on uniformly convergent sequences of functions. Detailed attention is paid to Osgood's uniqueness theorem for the afore-mentioned equation. Of course, the Picard method of successive approximations is also developed and used, and so is the famous Banach principle of fixed point with many applications. Beautiful are sections on dependence of solutions on the right-hand side of the given equation and on initial conditions.

The second main part deals in its three chapters and 25 subsections with systems of ordinary differential equations. Banach's principle shows its excellent possibilities here also. Chap. 5 gives general theory of linear systems and chap. 6 treats systems with constant coefficients. Reader's attention is called especially to attractive considerations on canonic forms of such systems. These equations are discussed on the basis of the theory of invariants and of elementary divisors. The stability of solutions in the sense of Liapunov is also treated.

Appendix contains five paragraphs devoted to partial equations of first order and with one unknown function. The almost linear, quasilinear, nonlinear, and Pfaff's equations are discussed.

The book carried off Stalin's prize for the year 1951 and its reading is an intellectual enjoyment for everyone interested in mathematics and its applications. The exactness and high viewpoint in presenting the subject remind one in many ways of the beautiful work "Differential equations" by R. A. Agnew. Reviewer hopes that the next edition of Petrovskiĭ's fine book will be completed with a detailed subject index.

V. Vodička, Czechoslovakia

3267. Ku, Y. H., Analysis of nonlinear systems with more than one degree of freedom by means of space trajectories, *J. Franklin Inst.*, **259, 2,** 115–131, Feb. 1955.

Paper outlines certain generalizations of the phase plane representation by considering Euclidian n-spaces with $x,\dot{x},\ddot{x},\ldots$ axes and by studying the phase trajectories in these spaces. Author gives examples of the three-phase spaces in the case of the van der Pol, Blasius, and some other equations. He considers also the cross sections by two-dimensional planes such as $(x,\dot{x})$, $(x,\ddot{x})$, $(\dot{x},\ddot{x})$, . . which permit gaining insight into the behavior of the trajectory. Systems with several degrees of freedom are treated in a similar manner. The procedure is essentially graphical and consists in plotting the slopes of trajectories from the assumed initial conditions.

Author observes that there are two choices in carrying out his procedure. One of them deals directly with n differential equations of the first order (the equivalent system) with n dependent variables. The other one operates with one single differential equation of the nth order using derivatives as dependent variables. On its face there seems to be no difference between the two procedures by virtue of the very definition of the equivalent system, but author prefers to explain this point in a later paper.

N. Minorsky, France

3268. Rosenberg, R. M., On the stability of a nonlinear non-autonomous system, *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. Mech. Engrs., 1955, 63–67.

The stability of solutions of the equation $\ddot{x} + a^2x + f(t)\,x^2 = 0$ is investigated for several types of functions $f(t)$. This type of differential equation arises in the stability of rolling elastic missiles and in dynamic systems where the forcing function is proportional to the square of the displacement. The functions $f(t)$ considered here are piecewise smooth. The cases investigated include those where $f(t)$ is monotone and (a) does not, or (b) does go to infinity with t, or (c) it is periodic with arbitrary period. In case (a) the solutions are found to be stable, in case (b) they are not, and in case (c) they are stable or unstable with those of a Mathieu equation. From author's summary

3269. Gusarov, L. A., On some properties of solutions of a linear differential equation of second order (in Russian), *Uchen. Zap. mosk. Univ.* **165,** *Mat. Sbornik*, **7,** 223–237, 1954.

Author gives a detailed analysis of some connections between bounds on the coefficient $p(x)$ in the equation $y'' + p(x)y = 0$ and distance between consecutive zeroes of the solution, the growth of the derivatives $y'(x)$ at these points, and the boundedness of the solution. A particularly interesting result is the theorem that $p(x) \geqq a^2 > 0$, and $p'(x)$ continuous and of bounded variation for $x \geqq x_0$ implies boundedness of all solutions of the above equation. R. Bellman, USA

3270. **Craig, E. J., The *N*-step iteration procedures,** *J. Math. Phys.* **34,** 1, 64–73, Apr. 1955.

In the matrix iteration method for solving the equation system $Ax = y$ (A is an $N \times N$ matrix, y the given, x the unknown N-dimensional vector), one visualizes the error $e_0 = x - x_0$ (x_0 is an approximate solution) as a vector $\sum_0^{N-1} m_k p_k$, where p_k are B-orthogonal base vectors: $p_j B p_k = 0$ for $j \neq k$. Ordinarily one chooses $B = A$. Author lists further possibilities.

G. Horvay, USA

3271. **Hammersley, J. M., and Morton, K. W., Poor man's Monte Carlo,** *J. roy. Statist. Soc.* (*B*) **16,** 23–28; discussion, 61–75, 1954.

This paper and the subsequent discussion relate chiefly to the art of applying Monte Carlo, and no brief summary can do justice to either. The basic thesis can be inferred from the title, that one does not necessarily need high-speed machines to use Monte Carlo effectively.

The authors first point out that only the name and not the method is new (the discussion brings out that King Solomon was an early practitioner) and then discuss three problems: the critical size of a nuclear reactor, the test of a quantum hypothesis, and self-avoiding walks. The last problem is treated at greatest length. The section headings are: Introduction; The problem of excluded volume in high polymers; Reducing the Monte Carlo work by choice of sampling technique; Reducing the Monte Carlo work by choice of recording technique; Inversely restricted sampling; Monte Carlo computing technique; Reporting Monte Carlo data; Estimation technique in Monte Carlo work; Artificial abatement of the randomness; Other sources of information.

A. S. Householder, USA

3272. **Tocher, K. D., The application of automatic computers to sampling experiments,** *J. roy. Statist. Soc.* (*B*) **16,** 39–61; discussion, 61–75, 1954.

Another paper (see preceding review) discusses Monte Carlo without, and the present paper with, high-speed machinery. Nearly half the paper is devoted to the development of a program for machine computation of the self-avoiding walk problem (thus proving, according to Hammersley and Morton, how difficult it is for machines to do "organizational," as distinct from arithmetic, work). The rest of the paper, and most of the discussion, relate to random and pseudo-random numbers, and to the question, when should Monte Carlo be used. Author gives an excellent discussion of the multiple-integral problem, comparing the adequacy of the Monte Carlo estimate with the numerical evaluation.

Probably the most useful portion of this paper is that which relates to random numbers. Topic headings include: Production of random sequences from nonrandom sequences; Production of uniformly distributed random variables; Sequences produced by recurrence relations; The "middle-of-the-square" process; The multiple method; Auto-regressive schemes; Suggested procedure for forming random digits on an automatic computer; Construction of samples from the common distributions on a computer.

The paradox of deterministically computing a "random" sequence naturally comes in for some discussion. This might have been made more profitable if the author had thought to make an important distinction: there are random processes, and there are sequences produced by random (or more or less random) processes, but there is no such thing as a random sequence (or set). For making certain assertions about the outcome of a Monte Carlo computation it is sufficient that the process producing certain data be random, but, as Hammersley and Morton point out in the discussion, this is not always necessary.

This is a minor criticism. On the whole, papers and discussion are well worth careful perusal by prospective practitioners.

A. S. Householder, USA

3273. **Saline, L. E., Quadratic programming of interdependent activities for optimum performance,** ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-58, 21 pp.

3274. **Dodge, H. F., Interpretation of engineering data: Some observations,** *Proc. ASTM* **54,** 603–638, 1954.

3275. **Drobot, S., On the foundations of dimensional analysis,** *Studia Math.* **14,** 84–99, 1953.

A paradox-free exposition of dimensional analysis is given, in which dimensional analysis is considered as the study of linear dependence relations in a real vector space. Thus power-products $L^\alpha M^\beta T^\gamma \ldots$ are construed isomorphically as linear combinations $\alpha L + \beta M + \gamma T \ldots$. An application to sampling theory is sketched [cf. S. Drobot and M. Warmus, *Rozprawy Mat.* **5,** 1954].

G. Birkhoff, USA

3276. **Eskenazi, M., Treatment and criticism of "Grandeur mesure, et unité" of Professor Max Landolt** (in French, with Turkish summary), *Bull tech. Univ. Istanbul* **5** (1952), 17–26, 1953.

M. Landolt's "Grandeur, mesure, et unité" [Paris, Dunod, 1947; translation of "Grösse, Masszahl und Einheit," Rascher, Zürich, 1943] is one of the recent attempts to set the theory of physical dimensions upon an axiomatic basis. The book itself is lengthened by many examples and much discussion; the author of the paper being reviewed devotes six pages to a formal exposition of Landolt's theory. There are two fundamental operations: one to represent combination of two magnitudes of the same dimension so as to form another of the same dimension, the other to denote generation of a quantity of new dimension. Under these two operations, dimensional quantities which are powers under the first operation of the unit element for the second operation are asserted to form a field isomorphic to the real field. [In the paper under review, only integer powers are defined; in the work of Landolt, we find general real powers used without any definition, although on p. 65 we read "nous postulons la validité des règles des puissances lorsque les mesures sont des nombres réels," and on p. 69 a similar statement.] The author expresses two objections to Landolt's theory: (1) It does not adequately represent the physical situation desired, since it permits us always to replace two quantities of like dimension by another, and (2) Landolt without physical justification has extrapolated properties of the real numbers to the calculus of dimensions. To illustrate the first objection, he remarks that two weights on a single balance pan are indeed equivalent to a single one, but two weights on the two pans are not equivalent to a single one. He concludes that the problem of axiomatization of dimensional analysis remains open. [What seems to the reviewer a more satisfactory set of axioms has been given by S. Drobot (see preceding review).]

C. Truesdell, USA

3277. **Sweeney, R. J., Measurement techniques in mechanical engineering,** New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1953, x + 309 pp.

This textbook is a useful compilation of instrumentation techniques commonly employed in mechanical engineering. The author has intended that his book should outline those measurement techniques which are commonly used in performance test-

ing of power equipment such as engines, pumps, compressors, and combustion and heat-transfer apparatus. An introductory chapter outlines things common to most instruments, such as readability, sensitivity, and hysteresis. Then follow ten chapters logically divided according to the type of measurement being made. Chapters on mensuration, mass, time and speed, electrical measurements, dynanometers, pressure, temperature, fluid flow, calorimetry, and chemical analysis provide a quick reference source and a consolidated review of performing measurements in these categories. The twelfth and last chapter, included for reasons unknown to the reviewer, concerns automatic controls. The general nature of floating, proportional, reset, etc., types of process control are discussed briefly. Although of possible interest to mechanical engineers unfamiliar with the topic, reviewer does not believe the subjects are pertinent to the general theme of the book.

The text is well supplied with pictorial illustrations, circuit diagrams and curves, as well as tabular numerical information on such things as typical instrument sensitivities, temperature ranges, sizes and the like, in addition to frequent presentation of empirical formulas useful in conjunction with the instrumentation described.

Reviewer believes that the book would be a worth-while text for an undergraduate course devoted to this general subject, as well as a ready source of information for the practicing engineer who wishes a quick review of the standard methods of measuring mechanical parameters in a field in which he is not primarily familiar. Greater emphasis should have been placed upon the dynamic limitations of various instruments, a consideration predominant in the thinking of the instrumentation engineer, and often underestimated by the mechanical engineer.

P. D. Wickersham, USA

3278. Nalband'yan, A., A problem on the construction of a graph of circles (in Russian), Nomographic collection, 123–124, Izdat. Moskov. Gos. Univ., Moscow, 1951.

A quantity which is a quadratic function of two independent variables is representable as a set of curves on a Cartesian grid. By the appropriate transformation of the Cartesian variables, the curves may be transformed into circles. This transformation is derived. Such transformations are given also by M. d'Ocagne ["Calcul graphique et nomographie," 2nd ed., Doin, Paris, 1914, 193–201]. M. Goldberg, USA

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 3277, 3296, 3311, 3320, 3349, 3354, 3423, 3574, 3575, 3579)

3279. Hiersig, H. M., Geometry and kinematics of evolute worm gears (in German), *Forsch. Geb. Ing.-Wes.* (*B*) **20,** 6, 178–190, 1954.

Author considers worm gears having worm teeth with an evolute surface and examines theoretically the geometrical and kinematic relationships of this form of gearing. Selecting first a triangular system of coordinates, he derives analytically the equations for the evolute surface and the ones for the face, axial, tangent sections, tangent plane, and normal lines. Next, he studies the points of contact and finds the area of contact analytically, deriving its equation. The field of contact, limited by the outer dimensions of worm and gear and undercutting, is determined for various gear ratios, number of worm teeth, etc. Contact ratios are deduced.

As a third step, the curvatures at various contact places are studied. Four worm-gear systems are examined and the radii of curvatures in eight planes along the contact line compared. Reviewer believes the paper offers an excellent theoretical contribution to the kinematics of gearing and urges some experiment verifying the relation of wear and curvature.

N. Theophanopoulos, Greece

3280. Bottema, O., On Alt's special three-bar sextic, *Proc. k. Ned. Akad. Wetensch.* (A) **57** = *Indag. Math.* **16,** 498–504, 1954.

If P_1, P_2, and P_3, three positions of a point in a plane body which moves over a fixed plane, have a circumscribing circle of constant radius, the locus of the center of the circle is a sextic curve which Alt [*ZAMM* **1,** 373–398, 1921] called an R_M curve. Alt showed that this curve can be generated by a point on the connecting rod of a coupler mechanism. Recent papers by Schuh [title source, (A) **57,** 92–103, 129–139, 140–151, 238–249, 250–262, 1954] considered the locus K of a point whose pedal triangle with respect to given triangle ABC has a circumscribed circle of constant radius. Schuh's curve is identical with Alt's curve. Bennett [*Proc. Lond. Math. Soc.* (2) **20,** 59–84, 1921] showed how to generate a sextic curve from a general plane cubic. It is shown that the sextic constructed from the cubic by Bennett's procedure is an Alt curve if, and only if, the three asymptotic lines of the cubic are the sides of an equilateral triangle. Also, the asymptotic lines are tangent to the circumcircle of triangle ABC. M. Goldberg, USA

3281. Boes, G. F. G., Kinematics of railroads (in Dutch), *Tech. Wet. Tijdschr.* **23,** 8, 181–204, Aug. 1954.

3282. Csonka, P., Statics [Statika] I, II, 2nd ed., Budapest, Tankönyvkiadó, 1951, 1954, 140 pp., 230 pp. 11.50 Ft., 35 Ft.

After a brief introduction dealing with fundamental principles, the first volume is divided into three main parts, covering forces in the plane, forces in space, and the centroids of lines, surfaces, and volumes.

The second volume deals with the determination of axial and transverse (shearing) forces and bending moments in statically determinate plane structures. This volume is divided into four main parts; a considerable part of this material is more likely to be found in a book on theory of structures than in a treatise on mechanics (statics) in English language texts. The first part explains the construction of shearing force and bending moment diagrams for beams; the second deals with forces in pin-jointed trusses. Arches, drawstring arches, bar chains, and ropes are covered in the third part; stability against sliding and overturning is treated in the last part.

The explanations are clear and concise, but they follow generally conventional lines. Considerable use is made of graphical methods in all plane problems; analytical methods are also freely illustrated by diagrams (approximately two figures per page). Worked examples are included and a few examples for solution are given at the end of every paragraph, but no solutions are supplied for these. (The solutions for the problems in the first volume and some from the second volume appear in "Problems in statics"; see following review). There is no alphabetical index provided.

The difficulties to be faced by small nations are brought home very strongly if it is noted that the present edition of the second volume was printed in 750 copies only. G. Sved, Australia

3283. Csonka, P., Problems in statics [Statikai példatár] I, II, Budapest, Tankönyvkiadó, 1951, 1954, 200 pp., 212 pp. 17.50 Ft., 32 Ft.

The two volumes contain 340 problems covering plane and spatial problems concerning concurrent, parallel, and other types of forces; centroids; axial and shearing forces and bending moments

in members with straight, bent, and curved center lines; and, finally, forces in members of plane pin-jointed trusses. The books—claimed to be the first comprehensive collection of this type of problems printed in Hungarian—are divided into two parts: the first part contains the problems set; the second part, after a very brief recapitulation of the principles involved, gives full solutions for all the problems included. The explanations are clear and they should provide considerable help to students. For the great convenience of the reader, the problems set are fully reprinted in the solution section, saving continuous reference to the first part of the book.

Although the paper and the binding are not up to the standards to which users of English language texts are accustomed, the printing is good, the figures are well drawn, and the books are remarkably free from errors. G. Sved, Australia

3284. Thomas, W., Friction-disk variable drives [Reibscheiben-Regelgetriebe] (edited by Niemann, G.), (Schriftenreihe Antriebstechnik, H.4), Braunschweig, Friedr. Vieweg & Sohn, 1954, viii + 79 pp., 76 pp. of figs., tables. DM 19.80.

A comprehensive summary of all types of friction drives for constant or variable speed using belts, cones, plates, spheres, rings, concave toroidal surfaces, and other cam surfaces. Among the special designs considered are those by Wesselmann, Prym-Köhl, Haynau, Flender, Sack, Hayes, and Arter. A thorough mathematical treatment, including multiple integration and elliptic functions, is given to the determination of forces, power, contact pressures, wear, heating, deflections, and testing. Included are tables of coefficients of friction for various mating surfaces under various pressures and temperatures. Extensive use is made of the ratio of the width of contact to the difference of contact radii and derived ratios. Tables and graphs of these values are provided for computing turning moments.

M. Goldberg, USA

3285. Rumyantsev, V. V., Case of S. V. Kovalevskaia for stability of the rotation of a heavy solid body with one stationary point (in Russian), *Prikl. Mat. Mekh.* **18,** 4, 457–458, July/Aug. 1954.

In the Kovalevskaia case, $A = B = 2C$; $x_0 \neq 0$; $y_0 = z_0 = 0$; A, B, C are the principal moments of inertia related to the stationary point; x_0, y_0, z_0 are coordinates of the center of gravity related to axes in directions of A, B, and C axes. It has been found that a necessary and sufficient condition for an absolute stability of motion of a heavy solid body about a stationary point is $x_0 < 0$. R. M. Evan-Iwanowski, USA

3286. Routh, E. J., Advanced part of a treatise on dynamics of a system of rigid bodies, 6th ed., New York, Dover Publications, Inc., 1955, xiv + 484 pp. $1.95.

This book is a re-issue of a classic reference in the field of dynamics. For those unfamiliar with its contents, a list of the 14 chapter headings will be sufficient explanation: Moving axes and relative motion; oscillations about equilibrium; oscillations about a state of motion; motion of a body under no forces; motion of a body under any forces; nature of the motion given by linear equations and the condition of stability; free and forced vibrations; determination of the constants of integration in terms of the initial conditions; calculus of finite differences; calculus of variations; precession and nutation; motion of the moon about its center; motion of a string or chain; and motion of a membrane.

Since this edition was first published in 1905, we find that some of the examples do not reflect the problems and advances of modern technology. Nevertheless, it is a valuable reference for those working constantly in dynamics (e.g., exterior ballisticians), and many in the field of applied mechanics will wish to have it on their bookshelves because it is frequently cited in the literature.

J. L. Lubkin, USA

3287. Thüring, B., A simple method for the computation of gravity components (application for an astronautical three-body problem) (in German), *Weltraumfahrt* **5,** 3, 69–72, July 1954.

In numerical integration of differential equations of motion of celestial mechanics one has to compute the components of gravity in the direction of the coordinate axes for a large number of positions of the bodies taking part in the motion. Author shows by means of a table that the computation of a single component of gravity in the case of two-dimensional motion is reducible to three operations (one multiplication and two divisions), while the direct computation requires six operations (one addition, three multiplications, one division, and one root extraction). In the case of three-dimensional motion, the computational work is reduced by means of a second table to four operations (one multiplication and three divisions), while the direct computation needs the performance of eight operations (two additions, four multiplications, one division, and one root extraction).

E. Leimanis, Canada

3288. Loiseau, J., Rational mechanics in four-dimensional space with applications (in French), *Publ. sci. tech. Min. Air Paris* no. 270, 312 pp., 1952.

The limitations of conventional mechanics are supposed to arise from its restriction to three dimensions. Author wishes to prove that a four-dimersioned differential geometry and quite a small number of mechanical axioms compose a sufficient basis for ordinary mechanics, electromagnetics, terrestrial magnetism, electronics, variation of mass with velocity, quantization of the trajectories, and statistics of light-quanta. He thinks that the mysteries about these things vanish when looked upon from the point of view of four dimensions.

The reader should, however, be careful. There are many misprints. Reviewer has not always been fully convinced of the validity of the arguments. It is well to check Loiseau cautiously before accepting and using his theses. O. H. Faxén, Sweden

3289. Stoppelli, F., A geometric representation of rotation and its application to astatics (in Italian), *Ric. Mat.* **3,** 95–107, 1954.

A rotation of a rigid body about a fixed point is given by an orthogonal matrix $||\gamma_{ij}||$. In view of the fact that there are ∞^3 rotations, author considers γ_{11}, γ_{22}, and γ_{33} as given and represents the rotation by the image point $P \equiv (\gamma_{11}, \gamma_{22}, \gamma_{33})$ in three-dimensional Euclidean space. The points P are shown to be the points within or on the border of a certain tetrahedron T. Each inner point of T corresponds to eight rotations. An application is given to a problem of astatics. A system of forces is in equilibrium and each force subjected to a rotation R. Author proves that the new system is again in equilibrium if the image of R belongs to a certain parabolic cylinder circumscribing T.

O. Bottema, Holland

3290. Kobrinskiĭ, A. E., Certain problems in the dynamics of elastic coupling mechanisms. Part 2, *Akad. Nauk SSSR Trudi Sem. Teorii Mash. Mekh.* **13,** 52, 49–88, 1953.

3291. Savin, G. N., On dynamic forces in a lifting shaft cable (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **97,** 991–994, 1954.

A lifting cable hangs over a revolving cylinder with fixed axis whose circular velocity is given. At the lower end of the cable a

load of weight Q is attached resting on a fixed base. Let the force applied to the lower end of the cable before lifting the load be $T_0 = \zeta_0$, where $0 \leqq \zeta \leqq 1$. As the cylinder begins to revolve, the lifting cable will first stretch out during an interval of time τ, the attached load remaining fixed on the support for $\zeta \neq 1$. The load will start to move upward only after the force applied to the lower end of the lifting cable attains the value Q. The cable is considered as an elastic-viscous string, i.e., its stiffness at bending is neglected.

Instead of the equations of motion for an element of the cable and the attached load, considered in a special case by Neronov [*Akad. Nauk SSSR. Prikl. Mat. Mekh.* (N.S.) **1**, 91–116, 1937], author introduces an integrodifferential equation (containing a parameter n) which is equivalent to the above-mentioned equations in the sense that any solution of these equations satisfying the prescribed boundary conditions satisfies also this integrodifferential equation. The converse theorem, however, is, in general, not true. By means of this integrodifferential equation author then constructs approximate solutions of the problem under consideration. E. Leimanis, Canada

3292. Lawden, D. F., Optimal programming of rocket thrust direction, *Astronaut. Acta* **1**, 1, 41–56, 1955.

The problems of fuel economy in true rockets are becoming increasingly important today in view of serious studies on long range missiles and satellite vehicles.

Author considers the problem of obtaining the maximum increment in energy for a given fuel expenditure for a rocket considered as a point mass and subject to the forces of thrust, aerodynamic drag, and gravity. A method, based on the variation of parameters, results in a mathematical system of algebraic and differential equations which must be solved simultaneously to determine the optimum thrust program. Of importance is the assumption that the method of fuel expenditure is predetermined and not optimized. In general, the equations can only be solved by numerical methods.

To illustrate some conclusions from the method, author obtains an analytical solution to the equations for the specialized case of no air density, uniform potential field, a constant thrust-to-mass ratio, and planar motion. For the particular case of a rocket launched from a satellite in which rocket escape is desired, it is shown that the optimum thrust direction deviates slightly from the trajectory tangent and toward the center of attraction, but this deviation decreases to zero at burnout. However, tangential thrust all the way is close to optimum. Transverse thrust (i.e., normal to lines of force) is shown not to be an economical thrust program. W. W. Berning, USA

3293. Lawden, D. F., Stationary rocket trajectories, *Quart. J. Mech. appl. Math.* **7**, part 4, 488–504, Dec. 1954.

Based on assumptions of known terminal points in space, the velocities at these points, and the mass at the final point, author derives set of fourth-order differential equations for a rocket path (stationary trajectory) which minimizes fuel consumption between the two points by dictating the optimum program of fuel expenditure. These equations consider the forces of thrust, gravity, and atmospheric drag, the last proportional to the velocity squared, acting upon a point mass. Additional drag from maneuvering is considered negligible.

Previous work indicates that impulsive thrusts, such as those imparted by boosters, effect a fuel saving. Author considers such impulses in derivations.

The problem of obtaining maximum altitude for a rocket fired vertically with assumed constant air density and gravity acceleration and with a given amount of fuel is solved analytically. The general equations are of such complexity as to require high-speed machine computation for their practical application.

W. W. Berning, USA

3294. Hudson, W. G., Conveyors and related equipment, 3rd ed., New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1954, vii + 524 pp. $9.

Book is greatly enlarged and aims to offer concrete information on materials-handling equipment for the plant and consulting engineer. Author does not deal with details of design. He gives very useful, comprehensive information to the student engineer. A fundamental knowledge of elementary matter is needed by the reader.

Individual chapters present different types of conveyors and elevators, storage, unloading of waterborne and car cargoes, mills and pulverizers, screens and feeders, weighing, drives and handling in power plants. A separate chapter deals with dust explosion hazards; it contains many new data, experiences, and experimental results. Consecutive chapters discuss the principles and main types of equipment, the criteria for selection, the fields of application and their limits. Also the operational data, capacities, determination of power requirements, maintenance, and, where possible, costs are discussed.

The book is of value because the many experimental and practical data are very useful in enabling one to compare and select the performance of the different equipment. It is useful for the designer, also. The data are completed by several graphs, figures, and numerical examples. A great number of excellent photographs is included. The book is clearly and systematically organized. G. Pattantyús, Hungary

3295. Heacock, F. H., and Jeffery, H., The application of power assistance to the steering of wheeled vehicles, *Instn. mech. Engrs. Auto Div.* **4**, 69–94, 1953–1954.

Servomechanisms, Governors, Gyroscopics

(See also Revs. 3268, 3474, 3586)

3296. Soroka, W. W., Response of dynamic systems, *Prod. Engng.* **26**, 4, 150–155, Apr. 1955.

Author presents in tabular form the response of various single-degree-of-freedom dynamical systems to a force function $F(t)$. Response is given in the form $x = A_1 + A_2 t + f(t)$. Values of A_1, A_2, and $f(t)$ are given for $F(t)$ a constant or power of t up to the sixth, and for sine, cosine, and exponential forms. The systems are a mass with (1) no spring or damping, (2) damping, (3) spring, (4) spring and light damping, (5) spring and critical damping, (6) spring and heavy damping. Since the systems are linear, superposition holds and examples are given of its applications. The author concludes by indicating how impulsive forces can be handled by means of the tables. The material and results are classical, but are presented in a convenient and useful form.

C. T. West, USA

3297. Spasskiĭ, R. A., On a class of regulated systems (in Russian), *Prik . Mat. Mekh.* **18**, 329–344, 1954.

The control system under consideration leads to a set of equations

$$x_i = \sum_{j=1}^{N} b_{ij} x_j + \sum_{s=1}^{m} h_{is} f_s(\sigma_s), \quad \sigma_s = \sum_{j=1}^{N} p_{sj} x_j \qquad [1]$$

where m is the number of regulating organs, the $f(\sigma)$ are nonlinear functions, the b, p, h are constants such that $||b_{ij}||$ has only

simple invariant factors of which k are zero ($n + k = N$). It is assumed that: (a) the $f(\sigma)$ are continuous and are such that, whatever the initial conditions, the system has a unique solution;

$$f_s(0) = 0, \quad \sigma_s f_s(\sigma_s) > 0 \quad \text{for } \sigma_s \neq 0 \qquad [b]$$

Let the system be reduced by linear transformation to

$$\dot{z}_i = \lambda_i z_i + \Sigma g_{is} f_s(\sigma_s), \quad i = 1, 2, \ldots, n$$

$$\dot{z}_{n+j} = \Sigma g_{n+j,s} f_s(\sigma_s), \quad j = 1, 2, \ldots, k \qquad [2]$$

$$\sigma_s = \Sigma \gamma_{s,j} z_j$$

Two questions are considered. (I) Necessary and sufficient conditions (n.a.s.c.) for the origin to be the sole position of equilibrium. It is proved that a necessary condition is $m \geqq k$. Furthermore, if $m = k$, then an n.a.s.c. for uniqueness of the origin in the above sense is $|\gamma_{s,n+\tau}| \neq 0$, $|g_{n+\tau,s}| \neq 0$; $s, \tau = 1, 2, \ldots, m$. (II) The asymptotic stability of the system. This is established (using the preceding results) by constructing effectively a suitable Lyapunov function. A number of special cases (small values of m, k) are discussed explicitly. S. Lefschetz, USA

3298. Sverdrup, N. M., Theory of hydraulic flow control, *Prod. Engng.* **26,** 4, 161–176, Apr. 1955.

In the design of any hydraulic circuit, the rate of flow is determined by the resistance of the various components and by the pressure differential across the circuit. Because, in spite of its importance, there is a serious lack of published data on hydraulic resistance, equations are derived for the flow rate of any circuit—including both parallel and series type. This is followed by a flow analysis of such components as valves, venturis, orifices, and other flow-limiting devices. Comprehensive examples illustrate the application of the analyses to practical design problems. From author's summary

3299. Turner, H. L., White, J. S., and Van Dyke, R. D., Jr., Flight testing by radio remote control—flight evaluation of a beep-control system, *NACA TN* 3496, 55 pp., Mar. 1955.

Handling-quality flight tests were conducted with an SB2C-5 drone under radio remote control from an F6F-5 control plane. Similar tests were conducted with the drone under manual control. A comparison of these tests indicates that the beep-type remote-control system investigated was generally satisfactory for flight testing an airplane via remote control, including take-off and landings. The restrictions and limitations of the present remote-control equipment are discussed. Suggestions are made for modifications to improve the equipment, both for the present drone and for possible application of the remote-control equipment to high performance airplanes.

With regard to system dynamic characteristics and the corresponding autopilot parameter settings, the tests indicated that the dynamic behavior would be satisfactory if the stabilized airplane satisfied a proposed transient-response criterion.

From author's summary by W. H. Phillips, USA

3300. Seamans, R. C., Jr., Barnes, F. A., Garber, T. B., and Howard, V. W., Recent developments in aircraft control, *J. aero. Sci.* **22,** 3, 145–164, Mar. 1955.

Paper deals with some basic philosophies of automatic control and human responses. Mathematics and mechanization of a pitch control system for aircraft are discussed, as well as its design analysis in nondimensional form. Consideration is given to changes in static stability, effect of fuselage bending, and location of gyro elements. Ability of system to minimize effect of gust interference is discussed. C. D. Pengelley, USA

3301. Morris, D., Shaft resilience in servo-mechanisms: Methods of compensating its effects, *Engineering* **178,** 4637, 756–758, Dec. 1954.

Author considers the problem of compensating for the presence of resilience in a shaft-gearing mechanism which connects the motor with the load in a servo-controlled device. Equations are worked out for the case where the motor and load can be considered as pure inertias and the coupling as a single flexible shaft. There follows a discussion of practical ways of installing error-sensing devices and of appropriate simple compensation techniques. H. M. Trent, USA

3302. Templates help plot frequency response, *Control Engng.* **1,** 3, p. 35, Nov. 1954.

3303. Firth, D., and Young, L., Some model experiments on special control valves, *Instn. mech. Engrs. Proc.* **168,** 13, 385–402, 1954.

Vibrations, Balancing

(See also Revs. 3265, 3267, 3286, 3296, 3343, 3572, 3573)

3304. Abramson, H. N., Resonance amplitudes in systems with a single degree of freedom, *Prod. Engng.* **25,** 8, 179–182, Aug. 1954.

Vibrating system under consideration has nonlinear restoring and damping forces; a harmonic disturbing force acts on system. Points in amplitude-frequency plane where the response curves intersect the curve of free undamped vibration define resonance.

Assuming harmonic vibration of the system and using the approximate method of W. Ritz, author derives a set of simple equations. As far as the approximation goes, solution of the equations determines the resonance amplitude. Examples given are linear damping with either hardening or softening restoring force, and square velocity damping. W. L. Esmeijer, Holland

3305. Popov, E. P., Natural vibration of high-order nonlinear systems subjected to slowly changing external action (in Russian), *Dokladt Akad. Nauk SSSR* **98,** 4, 545–547, Oct. 1954.

Author presents the differential equation of the nonlinear system of arbitrary order

$$Q(p)x + R(p)F(x, px) = S(p)f(t), \qquad p = d/dt$$

where $Q(p)$, $R(p)$, $S(p)$ are operational polynomials, $F(x, px)$ the nonlinear function, and $f(t)$ the external action.

Assuming that $f(t)$ and their derivatives change slowly with time, and if $f(t)$ is periodic function, then $\Omega \ll \omega$, the analysis is carried out on the basis of the successive approximations suggested by Krilov and Bogolyubov ["Introduction to nonlinear mechanics," Princeton Univ. Press, 1943].

The solution in the first approximation is presumed to take the form $x = x^0 + x^s = x^0 + a \sin u$, $\omega = du/dt$. Using the harmonic linearization to the nonlinear function F under assumption that the value $S(p)f(t)$ has the slow rate of change, the above differential equation is reduced, taking into consideration earlier results [AMR **8,** Rev. 1578] on three equations

$$x(a, \omega, x^0) = 0; \qquad Y(a, \omega, x^0) = 0; \qquad Q(p)x^0 + R(p)q^0 = S(p)f(t)$$

with the unknown quantities a, ω, x^0, which depend on time also.

In several practical cases it is enough to determine the vibrations of the system for different constant values of f^0; then the unknown quantities are constant too, in consequence of which the

procedure is facilitated. Knowing the functions $a(f^0)$, $\omega(f^0)$, the character, amplitude, and frequency alteration for the vibrations when $f(t)$ is changing very slowly can be estimated.

The above results for $f^0 = 0$ can be used for the first approximation of the system with nonsymmetrical nonlinearities in cases when the external action is not presented. (See also following review.) D. Rašković, Yugoslavia

3306. Popov, E. P., More accurate approximation in the investigation of the natural vibrations of high-order nonlinear systems (in Russian), *Dokladi Akad. Nauk SSSR* **98,** 3, 345–348, Sept. 1954.

Contrary to the previous treatment [AMR **8,** Rev. 1578], in this paper author deduces more accurate approximation of the system governed by equation $Q(p)x + R(p)F(x, px) = 0$, $p = d/dt$ where $Q(p)$, $R(p)$ are the operational polynomials and $F(x, px)$ is the nonlinear function, in the case when it is necessary for the harmonic linearization to also take into consideration the higher harmonics of the argument. The first harmonic of F can be prescribed by means of the first and several significant higher harmonics of x. For this purpose, the formula of the linearization must be accurate.

The periodic solution is presumed to be a Fourier series with n significant harmonics [$x_k = a_k \sin(k\omega t + \varphi_k)$], and the basic equation is transformed into a system with n equations. Using the two assumptions, proposed by Bogolyubov (first, the first harmonic is dominant; second, for higher harmonics, the small accuracy is sufficient), the coefficients of the first harmonic of F are ameliorated with terms q' and q_1', which are the functions of $a = a_1$, ω, and of a_k, φ_k of each harmonic. By means of the coefficients r_k, s_k of the higher harmonics of F (which depend on a, ω, and only of a_k, φ_k, of the same harmonic), since $\pi a_k e^{i\varphi_k} = \phi(a, \omega)$, the phase φ_n for arbitrary a can be determined in the complex plane. Further, in the plane, a_k, φ_k and the functions of $a_k(a, \omega)$, $\varphi_k(a, \omega)$ can be obtained. In this way the determination of the amplitude and the circular frequency of the fundamental harmonic are reduced on an earlier mode. The value ω can be obtained graphically.

The cited bibliography is exclusively in Russian.

D. Rašković, Yugoslavia

3307. Uno, T., On subharmonic resonance, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 307–308.

Author considers the system

$$-dn/dt = X(x, y) + kp(t)$$
$$dy/dt = Y(x, y) + kq(t) \qquad [1]$$

and he supposes: (a) $p(t)$, $q(t)$ are periodical functions of t of period τ; (b) if $k = 0$, [1] has a periodical solution of period $\lambda\tau$. Author shows the possibility of a stable periodical solution of [1] with period $n\tau$, where there is an integer number near λ. This possibility is confirmed by some numerical examples.

D. Graffi, Italy

3308. Sinclair, D., Frictional vibrations, ASME Ann. Meet., New York, N. Y., Dec. 1954. Pap. 54—A-46, 8 pp.

Author gives experimental data on self-excited vibrations produced by frictional effects between brake lining and cast-iron base. Such vibrations produce automobile brake squeal, for example. Conditions studied were slow uniform motion and rapid simple harmonic motion produced by mechanical vibrator. Mathematical analysis of system is given, and it is concluded that vibration is due to drop in friction coefficient with increasing sliding velocity. By treating rubbing surfaces with certain organic compounds so that coefficient increased with sliding velocity, vibration could be eliminated; however, this was not considered a satisfactory method in practice since abrasion and high temperature eventually destroy surface treatment.

A. M. Wahl, USA

3309. Davidson, J. F., The dynamic lateral instability of beams, *Proc. roy. Soc. Lond.* (*A*) **226,** 1164, 111–128, Oct. 1954.

The vibrations are analyzed of a deep, slender beam subject to pure bending in the plane of maximum stiffness. It is shown that a coupling of the lateral bending and torsional modes results, these modes being replaced by two independent modes, each involving torsion and flexure. One of these modes is associated with a frequency which decreases with increasing applied moment and becomes zero when the critical moment for lateral instability is reached. The other mode is associated with a frequency which increases with applied moment. Experiments were carried out on an I-section and gave results which are in reasonable agreement with theory.

From author's summary by G. Winter, USA

3310. Cox, H. L., and Klein, B., Vibration of isosceles triangular plates, *ZAMP* **6,** 1, 68–75, 1955.

Paper presents an approximate solution for the gravest natural frequency using the method of collocation. Simply supported and clamped plates are treated, and the results are found to be within a few per cent of known cases. A convenient calculating curve is given. J. L. Lubkin, USA

3311. Irie, T., and Konishi, K., An experiment on the oscillation of a suspended chain (in Japanese), *Trans. Japan Soc. mech. Engrs.* **21,** 103, 206–211, 1955.

3312. Shea, J. F., An anti-resonant damper for dancing cables, *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 127–133.

The "dancing" or "galloping" of aerial lines has long been a problem for telephone and power companies. Dancing is a large amplitude, low frequency oscillation of the line usually in one of its first four modes. The amplitude may be as large as ten feet, and the frequency is the order of one cps. The motion is apparently caused by the aerodynamic instability of the cross section of the line in a side wind.

This paper develops the theory of a simple antiresonant damper which may be attached to the cable to prevent excessive amplitudes of motion. From author's summary

3313. Fiszdon, W., The use of the admittance method in calculating forced aircraft vibration amplitudes, taking into account internal damping (in Polish), *Arch. Bud. maszyn* **1,** 2, 123–164, 1954.

The concept of the admittance method introduced by Carter as dynamic flexibility is better known now as the receptance method. The main advantage of the receptance method is that it permits complicated systems to be broken down into simpler parts. Until now the practical possibilities of the method have not been thoroughly explored. Mr. Fiszdon extends the method to complex systems with internal damping.

In the first part he introduces the receptance by developing elementary vibration formulas. (The same results could be obtained by substituting $1/q$ where q is receptance, instead of K for stiffness in well-known formulas.) Later he derives receptance formulas for flexible beams (for bending and torsion), assuming that internal damping is proportional to the velocity of the de-

formation; further, for a body suspended on four springs with damping, he calculates receptance of a complex system from the receptance of known elements.

With examples for various damping (0.025 to 0.3 of critical) of a flexible three-mass system (aircraft frame), he shows the influence of damping on forced vibration in this particular case. Aircraft vibrations can be reduced by larger damping in the frame and an engine suspension system which is softer and has larger internal damping.

This interesting study of theoretical and practical importance is concluded with a calculation of approximate receptance in complex cases by Galerkin and Lagrange methods.

A. L. Nasvytis, USA

3314. Kobori, Y., Experiment on vibration of rotating blades having cross sections of several kinds, *Proc. 1st Japan nat. Congr. appl. Mech.*, 1951; Nat. Committee for Theor. appl. Mech., May 1952, 547–550.

This paper describes the determination by experimental means of the centrifugal force factor B, used to correct standing frequency of turbine blades to frequency at speed. The frequency at speed f is expressed by the formula, $f^2 = f_s^2 + Bw^2$, where f_s is the frequency of the blade at rest and w is the speed of the wheel, frequency and speed being expressed in cps. Three types of blades were tested: (1) Constant cross section; (2) area and moment of inertia vary linearly with length, the area of the base being twice the area at the tip; (3) area and moment of inertia vary linearly with length, the area of the tip being zero. These blades were all made of flat stock of constant thickness. The B factor was determined experimentally for the first three frequencies. A correlation was made with calculated values. The correlation was fair in the first fundamental frequency for two constant cross-sectional area blades tested, but was off by as much as 44% in other cases.

In the opinion of the reviewer the apparatus is quite ingenious and should give good results; the discrepancy between test and calculated values might be due in part to the method of fastening the blades to the rotating device. The data should be useful in cases in which the B factor is required, for higher modes, with blades in which the area and moment of inertia vary linearly with the blade length.

E. G. Allen, USA

3315. Johnson, D. C., A note on the excitation of vibrating systems by gearing errors, *J. roy. aero. Soc.* **59,** 534, 434–435, June 1955.

3316. Grohne, D., Spectrum of the natural vibration in two-dimensional laminar flow (in German), *ZAMM* **34,** 8/9, 344, 357, Aug./Sept. 1954.

The stability investigation of laminar flow by the method of small vibrations leads to a nonself-adjoint boundary-value problem with a fourth-order ordinary differential equation. The natural vibrations of this boundary-value problem considered so far have been mainly neutral and forced. In this paper, the complete spectrum of the eigenvalues c as well as the form of the natural vibrations is investigated.

From author's summary by H. C. Levey, Australia

3317. Kanwal, R. P., Vibrations of an elliptic cylinder and a flat plate in a viscous fluid, *ZAMM* **35,** 1/2, 17–22, Jan./Feb. 1955.

Paper presents formal solutions to the problems of an oscillating elliptic cylinder in an incompressible viscous fluid. By linearization of the Navier-Stokes equations in elliptic coordinate system, series solutions involving Mathieu functions are obtained for two cases where the cylinder oscillates either along the major or minor axes.

Y. H. Kuo, USA

Wave Motion in Solids, Impact

(See also Revs. 3572, 3573)

3318. Babich, V. M., Equations of motion of nonlinear elastic media (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **97,** 1, 41–44, July 1954.

The author considers the Hencky-Schmidt system

$$\sum_{j=1}^{3} (\partial/\partial x_j)(\partial\pi/\partial e_{ij}) = \rho\,(\partial^2 u_i/\partial x_0^2)$$

where

$$\pi = \epsilon^2/6k + \int^{\Gamma^2} g(\zeta)\,d\zeta$$

with the medium assumed resistive. Since a solution of the above equation will yield the wave velocity, it is found that, for cases of $\Gamma^2 > 0$, the velocities of the fastest and slowest waves are dependent on orientation, while the velocity of those in between is not.

It is further stated that it is possible to relate this effect with the plastic behavior of rocks and to substantiate this if it results from a Hencky-Schmidt type system of media.

N. M. Matusewicz, USA

3319. Schnitzer, E., Theory and procedure for determining loads and motions in chine-immersed hydrodynamic impacts of prismatic bodies, *NACA Rep.* 1152, 29 pp., 1953.

Supersedes article reviewed in AMR **6,** Rev. 1827.

Elasticity Theory

(See also Revs. 3318, 3350, 3352, 3353, 3356, 3361, 3365, 3367 3368, 3371, 3378, 3380, 3388)

3320. Rašković, D., Collection of problems on strength of materials and tables [Zbirka zadataka iz otpornosti materijala. Drugo preradeno i dopunjeno izdanje, i tablice], Beograd, Naučna Knjiga, 1955, 1952, vii + 258 pp., 132 pp.

Book is written on an elementary level and contains the solution of 550 general elementary problems in the field of mechanics. The tables are added to the book containing general information regarding the theory covered by the problems.

Book is particularly recommended for those needing basic background information on topics covered in undergraduate courses for engineers.

M. M. Stanišić, USA

3321. Manacorda, T., On a variational principle of E. Reissner of the statics of continuous media (in Italian), *Boll. Un. Mat. Ital.* (3) **9,** 154–159, 1954.

E. Reissner [AMR **4,** Rev. 2381] has obtained for classical linear elasticity an elegant variational principle which is equivalent to the differential equations of equilibrium, the stress-strain relations, and mixed boundary conditions. Subsequently [AMR **7,** Rev. 1042], he has generalized it to a particular class of theories of finite strain. Apparently unaware of the second paper of Reissner, the author attempts to obtain an extension to the general theory of finite elastic strain. [How far this attempt can be successful may be seen in advance by noticing that in Reissner's original proof the theory of elasticity is defined by (1) strain energy = function of stress, and (2) strain = gradient of energy with respect to stress, but (3) makes no direct use of the symmetry of the stress tensor, which emerges only through the stress-

strain relations. All that is needed is to find a formalism for the finite theory in which (1) and (2) hold, then duplicate Reissner's steps. As is well known, (1) is not true in general (i.e., the stress-strain relations cannot be inverted in the large), but if (1) is assumed, (2) follows, provided the "stress" is taken as Kirchhoff's double vector $T^{1\alpha}$, which is not symmetric [cf. (3) and §39 of the reviewer's paper, *J. rat. Mech. Analysis* **1**, 125–300, 1952]. The author follows this plan, although he fails to mention that (1) is a restriction which generally will invalidate the variational principle except for sufficiently small portions of the material. It should be noted also that the variational integrand as written is not a scalar unless both deformed and undeformed systems of coordinates are rectangular Cartesian. The author concludes by using the variational principle to derive the stress-strain relations of Finger for isotropic elastic bodies. C. Truesdell, USA

3322. Cornish, R. J., Influence lines by Williot-Mohr diagrams: Application of Maxwell's reciprocal theorem, *Engineering* **178,** 4639, 827–829, Dec. 1954.

3323. Schlechtweg, H., Strain measurements in cast iron (in German), *Z. Metallk.* **45,** 12, 690–694, Dec. 1954.

The usual expressions of Hooke's law (stress in terms of strain, modulus, and Poisson's ratio) are not usable for cast iron since they are valid only for a modulus independent of the strain. Author has shown it to be expedient to take as the true modulus that part which has been neglected and, by tensor analysis, derive a strain function. From this function and the principal strains he arrives at expressions for the sum and differences of the principal stresses. Paper is composed mostly of the detailed tensor analysis and an illustrative example. Absence of sufficient explanatory matter makes evaluation difficult. It appears, however, as an effort in a highly desirable direction: that of establishing stress- and/or strain-dependent expressions for the modulus of elasticity. C. C. Osgood, USA

3324. Sternberg, E., and Eubanks, R. A., On the concept of concentrated loads and an extension of the uniqueness theorem in the linear theory of elasticity, *J. rat. Mech. Analysis* **4,** 1, 135–168, 1955.

The solution of the second boundary-value problem of the linear theory of elasticity rests in its traditional formulation on three conditions: It must satisfy the field equations throughout the medium; it must conform the boundary conditions for distributed surface tractions; and it must be regular with the exception of singularities at the points of application of concentrated loads. These conditions are sufficient for the classical uniqueness problem, which does not hold for concentrated loads. After geometric preliminaries and generalizations of the classic reciprocal and uniqueness theorems, some problems with external and internal loads are discussed. By means of a limit process, authors show that it is sufficient for boundary problems with concentrated loads to require the fourth condition, namely, the order of the stress-singularities at each point of application of a concentrated load is r^{-2}, where r is the distance from the load point. It is proved that this condition—together with the afore-mentioned three—represents a unique characterization of the solution of boundary problems with concentrated loads.

H. Neuber, Germany

3325. Huber, A., The elastic sphere under concentrated torques, *Quart. appl. Math.* **13,** 1, 98–100, Apr. 1955.

The note discusses an elastic sphere subject to two concentrated torques acting at the end points of a diameter. The stress function occurring in this problem is considered as a generalized axially symmetric potential. This viewpoint enables one to obtain the solution by a simple potential-theoretic argument.

From author's summary

3326. Silverman, I. K., Approximate stress functions for triangular wedges, *J. appl. Mech.* **22,** 1, 123–128, Mar. 1955.

The stress function for infinite wedges is known for several important loading conditions. Paper discusses approximate stress functions which are to be superimposed in order to satisfy the b.c. along a third boundary. Auxiliary stress function is assumed in the form $f(y)g(x, y)$, where $g(x, y)$ is chosen such that b.c. along 2 wedge boundaries are satisfied for all $f(y)$. Latter function is determined from principle of least work by means of calculus of variations. One example (hydrostatic load on triangular dam) is given. W. T. Koiter, Holland

3327. Gulkanyan, N. O., On torsion of a prism of triangular cross section (in Russian), *Akad. Nauk Armyan. SSR. Izv. Fiz. Mat. Estest. Nauk* **6,** no. 5/6, 69–76, 1953.

An approximate solution of the Saint Venant torsion problem for a beam with a triangular cross section is deduced when the section is an isosceles or a right triangle. The boundary conditions are satisfied approximately by minimizing the square of the error in the assumed series solution.

I. S. Sokolnikoff, USA

3328. Conway, H. D., Further problems in orthotropic plane stress, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-48, 3 pp.

3329. Vaisey, G., and Hemp, W. S., Solution of a load diffusion problem by relaxation methods, *Coll. Aero. Cranfield Note* no. 17, 19 pp., Nov. 1954.

A stringer-stiffened rectangular plate, simulated as an orthotropic plate, bordered by three elastic bars and fixed at fourth edge, is analyzed numerically. Opposite to the fixed edges, the plate is welded to an end rib of negligible flexural rigidity but of finite cross section, while the other two edges are connected to end booms which offer both bending and extensional restraint. Two concentrated loads are symmetrically applied parallel to the boom at the corners where they meet the rib.

The equations of equilibrium in terms of the component displacements are replaced by finite difference approximations. A square network was used resulting in irregular mesh size at two boundaries. The network is further subdivided in the neighborhood of the corner.

The results of the analysis for a particular case are elaborately illustrated in nine figures. The authors state that full agreement has not been achieved with experimental work to which they refer without description. N. M. Newmark, USA

3330. Oxford, C. J., Jr., and Cook, J. A., The influence of tap-drill size and length of engagement upon the strength of tapped holes, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-85, 18 pp.

3331. Lakshmana Rao, S. K., and Sundara Raja Iyengar, K. T., Problems connected with the rhombus, I: Elastic torsion, *J. Indian Inst. Sci.* (*B*) **36,** 159–171, 1954.

Authors study the torsion problem for a rhombus of side a and angles $2\theta, \pi - 2\theta$. Using the Rayleigh-Ritz method with polynomials of degree 6 satisfying the boundary condition, and a method of Friedrichs with harmonic polynomials of degree 4, they obtain lower and upper bounds for the torsional rigidity D for arbitrary values of θ. For $2\theta = 60°$, $0.09093 < T < 0.0951$, where

$T = D(\mu a^4)$. Comparison with a circle of the same area gives $T < 0.1194$, and symmetrization with respect to a perpendicular to a side gives $T < 0.1051$. The bound $T > 0.0433$ is obtained by regarding the rhombus as the union of two equilateral triangles. Finally, they triangulate the rhombus and use relaxation methods, obtaining an approximation $T = 0.09121$. All the numerical results quoted above are for $2\theta = 60°$. [The authors do not seem to be aware that the method of triangulation might have been used to obtain rigorous bounds; cf. J. L. Synge, *Rendiconti di Matematica e delle sue applicazioni* (5) **10**, 24–44 (Roma, 1951); Proc. Symposia in applied mathematics, **IV**, Fluid dynamics, pp. 141–165, New York, Toronto, London, McGraw-Hill Book Co., Inc., 1953; AMR **7**, Rev. 1846.]

J. L. Synge, Ireland

3332. Narasimhamurthy, P., Torsion of multiply connected sections, *J. Indian Inst. Sci.* (*B*) **36**, 150–158, 1954.

In the torsion problem for a hollow shaft we have to find a stress function ϕ to satisfy $\Delta\phi = -2$ with $\phi = 0$ on the outer boundary and $\phi = C$ on the inner boundary B, the constant C being determined by the condition $\oint_B (\partial\phi/\partial n)ds = -2A$, where A is the area inside B. Author is concerned with the approximate calculation of C, the solution ϕ_1 for the solid shaft with the same external boundary being given. He uses the formula [*] $C^2 = \int^{2\pi} \phi_1^2\, ds/2\pi$, where the integration is around B, the parameter s running from 0 to 2π. The formula [*] is deduced as an approximation from another formula [**] $\int\int \phi_1 dx\, dy = \int\int \phi dx\, dy$, the integrals being taken through the material of the hollow shaft. Two numerical solutions are worked out with satisfactory results.

The argument is very difficult to follow. The formulas [*] and [**] are true for a ring bounded by concentric circles, and apparently this is the fact which gives the work some practical validity. Author takes the inner boundary circular, but the outer boundary is general, and the method seems to be without any proper mathematical justification. He appears to assert that [**] is true in general, which cannot be correct.

J. L. Synge, Ireland

3333. Ericksen, J. L., Deformations possible in every isotropic, incompressible, perfectly elastic body, *ZAMP* **5**, 6, 466–489, 1954.

Rivlin's solutions of some special problems of large elastic deformation allowing the strain-energy function of the material to remain arbitrary lead to the question of what kinds of deformation can occur in all materials. Any continuous displacement field can be imposed, its strain tensor found, and its stress tensor will follow from the strain-energy function. In general, equilibrium demands body and surface forces. If, as here, there are to be no body forces, the stress tensor is restricted by the equilibrium conditions $t_{,j}^{ij} = 0$. The strain tensor will be correspondingly restricted through the strain-energy function. The paper considers what strain conforms to this, in isotropic incompressible material, regardless of the strain energy function, as, for instance, homogeneous strain does. Some such deformations are found explicitly, involving flexure, extension, and shear of a rectangular piece of a thick cylinder or flat slab. Three of these are believed new.

J. N. Goodier, USA

3334. Morgan, A. J. A., Stress distributions in semi-infinite solids of revolution, *ZAMP* **5**, 4, 330–341, 1954.

Using a recently developed theory for obtaining "similarity-solutions" (rather, "invariant solutions") or partial differential equations, author reduces the ∇^4 equation of Love for solids of revolution to a total differential equation which is solved by combinations of Legendre functions. By this procedure he derives formulas for the state of stress (a) in a plate of infinite radius and linearly varying thickness (b, c) in a semi-infinite conical shell and a solid cone, all under loads varying as a real number power of the distance from the apex.

K. Marguerre, Germany

3335. Hoyle, R. D., Transient temperature stresses in axially symmetrical systems with special application to a solid rotor of a steam turbine, *Proc. Instn. mech. Engrs.*, 3–8, Apr. 1955.

A method of determining thermal stresses in axially symmetrical systems is described. The method is applicable to any axially symmetrical body of irregular shape in which temperature gradients occur in both radial and axial directions, such as ingots, gas turbine disks of appreciable thickness, and steam turbine rotors. A convergent numerical solution can be obtained by relaxing two governing equations. Thermal stresses can be obtained for any known transient or steady-state temperature distribution. Application of method to a steam turbine rotor to determine the required steam entrance conditions and warm-up time if stresses are to remain below the elastic limit is given. Method may be used in conjunction with a computing service to obtain solutions to a variety of problems.

From author's summary by E. L. Foster, USA

3336. Nowacki, W., Thermal stresses in anisotropic bodies I (in Polish), *Arch. Mech. stos.* **6**, 481–492, 1954.

Author deduces the Betti-Rayleigh reciprocal theorems for a nonhomogeneous anisotropic elastic body subjected to nonuniform heating and obtains the formulas for the mean deformations in the heated body.

I. S. Sokolnikoff, USA

3337. Manson, S. S., Behavior of materials under conditions of thermal stress, *NACA Rep.* 1170, 34 pp., 1954.

Supersedes articles reviewed in AMR **7**, Revs. 436, 1743.

3338. Kessler, G. W., Principles of boiler design for high steam temperatures, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-233, 13 pp.

Experimental Stress Analysis

(See also Rev. 3359)

3339. Perry, C. C., and Lissner, H. R., The strain gage primer, New York, Toronto, London, McGraw-Hill Book Co., Inc., 1955, xi + 281 pp. $6.

In contrast to the number of texts on theoretical mechanics, very few are as yet available covering the recently developed but already very popular strain-age techniques. During their development, the worker in this field for the most part had only the periodical literature from which to inform himself, and a publication which condenses the essentials into a single volume for quick reference, as does this one, is to be welcomed.

Emphasis throughout is upon the wire strain gage. Following a general introduction to what it will do, the book covers in greater detail the background needed for intelligent practical application of the gage. Included are gage selection, bonding, bridge circuit theory, temperature compensation, long-term use, and other factors.

Instrumentation is covered sufficiently to enable the mechanical engineer to select equipment of the proper characteristics for a given application and to permit him to use it quantitatively. Problems arising in the recording of transients, however, are not discussed.

Attention is given to special techniques, such as the use of ceramic gages for extreme temperatures, and to representative transducer applications wherein not strain but force, displacement pressure, or other quantities can be measured. These are sufficiently varied to suggest to the reader other applications to suit his own problems. Issue may be taken by some regarding a few points in the book; e.g., the relative merits of certain slip-ring and brush materials—but this is to be expected in a field still under development. The final chapter discusses the complementary brittle-coating technique.

Book is very clearly written and should be of interest to both the technician and the engineer. It is believed it will prove valuable as a reference for college courses in experimental stress analysis, for industrial laboratories, and for practicing engineers not specializing in this field but who, on occasion, could well profit from a single source of the necessary background for successfully organizing and carrying out a project.

C. W. Gadd, USA

3340. Vasarhelyi, D. D., A resistance-wire grid system, *Trend Engng. Univ. Wash.* **7,** 2, 5–9, 14, Apr. 1955.

Experimental determination of stored energy due to tensile loading required mapping longitudinal and transverse plastic deformations of a large steel plate containing a cutout. This was accomplished by use of a 130-point resistance slide-wire grid system covering an area 24 × 36 in. and employing a switching panel and modified SR-4 strain indicator. The design of the slide-wire grid and related apparatus, which allowed measurement of plastic strains during nearly continuous loading at low temperatures, is described. H. T. Corten, USA

3341. Ripperger, E. A., A piezoelectric strain gage, *Proc. Soc. exp. Stress Anal.* **12,** 1, 117–124, 1954.

3342. Kobayashi, A. S., and Day, E. E., Recording interferometer for strain gage calibration, *Proc. Soc. exp. Stress Anal.* **11,** 1, 235–238, 1953.

3343. Koch, J. J., Measuring on steel structures (in Dutch), *Ingenieur* **66,** 44, W.145–W.150, Oct. 1954.

Only those measuring methods are discussed that can be applied to large steel structures in the open air. Several methods are described to measure displacemets, vibrations, strains and forces. For strain measurements, the resistance strain gage in most cases is superior to other strain gages.

From author's summary

3344. Hakkeling, B., An experimental determination of the coefficient of end restraint of a compressed stiffened panel, *Nat. LuchtLab. Amsterdam* Rap. S.442, 15 pp., June 1954.

The end restraint of a compressed flat plate, stiffened by stringers, is determined from the wave length of the stringer deformation. This deformation is disturbed by the influence of membrane forces, due to plate buckling. Elimination of the latter results in the conclusion that this panel can be considered as built-in. From author's summary

3345. Rogin, L., Theory and techniques of calibration for structural flight load measurement, *Proc. Soc. exp. Stress Anal.* **11,** 2, 69–80, 1954.

A general approach to the problem of evaluating flight loads imposed on aircraft structural components by means of measured strains in the structure is presented. Laboratory calibration of the instrumented component is obtained in terms of indicated strains resulting from the application of known loads. It is shown that the basic form of the load calibration equations and the number of equations required for a given installation are established by means of a structural analysis of the component involved. The methods to be used in establishing the final form of the equations, as a result of a comprehensive laboratory test program, are described. Application of the general theory is illustrated by the load calibration of an airplane wing.

From author's summary by J. DeYoung, USA

3346. Kawada, Y., Watanabe, S., Takano, K., and Kawamura, K., Improvement in the measurement of the residual stresses in a plate, *Proc. 1st Japan nat. Congr. appl. Mech.*, 1951; Nat. Committee for Theor. appl. Mech., May 1952, 225–229.

3347. Ōkubo, H., and Satō, S., Stress-concentration factors in shafts with transverse holes as found by the electroplating method, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-88, 4 pp.

The torsion of shafts with transverse holes is investigated experimentally. Usual methods for stress measurements, such as the method of brittle coatings and the use of sensitive extensiometers, are not applied effectively to the present problem because the maximum stress occurs in the bore and does not occur in the outer surface of the shaft. The stress may be measured by the stress-freezing and slicing method, but too much cannot be expected from this method for the accurate determination of the stress when the diameter of the hole is comparatively small. In treating the problem theoretically, considerable mathematical difficulties are encountered because of its axially nonsymmetrical nature. The electroplating method recently developed by one of the authors, however, has been proved to be useful in this case, so the maximum stresses in shafts are measured by this method and the stress-concentration factors are found for various diameters of the hole. From authors' summary

3348. Meyer, J. H., Test development of structures designed understrength, *Aero. Engng. Rev.* **13,** 10, 54–64, Oct. 1954.

Stretch testing, in which structures are designed understrength and brought up to strength by successive static tests, is discussed. The benefits of weight saving in general are brought out and an approximate criterion for the value of weight presented. Data are presented on the scatter and stretch observed during various test programs. The sources of inaccuracy of analytical strength determinations are enumerated. Examples of stretch programs are described and the benefits discussed. A design process for exploiting stretch testing is described, and several factors entering into the choice of stretch-test methods are discussed. It is concluded that stretch testing is an extremely valuable tool in developing efficient aircraft structures.

From author's summary

Rods, Beams, Cables, Machine Elements

(See also Revs. 3279, 3284, 3290, 3291, 3309, 3319, 3332, 3333, 3379, 3392, 3434)

3349. Selig, F., The potential concept in the motor method and its application to thin rods (in German), *ZAMM* **34,** 8/9, 327–328, Aug./Sept. 1954.

The work done by a wrench (force motor) in the infinitesimal screw displacement is expressed by true (e.g., Rodrigues) coordinates of the rigid body in place of the quasi-coordinates of angular velocity. Introducing symbolic motor differentiation in the conservative case, the force motor takes the form of a gradi-

ent. Paper hints at the treatment of problems in the theory of thin rods with aid of this new concept.

H. Schaefer, Germany

3350. Nishihara, T., and Fujii, T., Stresses in a filleted round bar under tension, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 79–82.

The stress concentrations at the surface of a filleted round bar under a tensile load are obtained by separation of the bar into two parts and then equating the stresses and deformations of the two parts at the separating surface. C. B. Matthews, USA

3351. Nowacki, W., On certain cases of torsion of bars (in Polish), *Arch. Mech. stos.* **5**, 21–46, 1953.

An exact solution is obtained for the Saint Venant torsion problem of orthotropic bars for the following cross sections: (1) a rectangle with narrow slits; (2) a section whose components are rectangles; (3) an annular sector; (4) a circle with rectilinear or curvilinear slits. The problem is formulated with the aid of the membrane analogy and the solution is deduced from the appropriate Fredholm integral equations of the first kind.

I. S. Sokolnikoff, USA

3352. Nowinski, J., The torsion of a rectangular rod in which one cross section remains plane (in Polish), *Arch. Mech. stos.* **5**, 47–66, 1953.

An approximate solution is obtained for the torsion problem of a rectangular rod, one of whose cross sections is constrained to remain plane. The method used is that proposed by S. P. Timoshenko [AMR **5**, Rev. 43] for the solution of the corresponding problem for a narrow rectangular beam.

I. S. Sokolnikoff, USA

3353. Kuroki, K., Shearing stresses of elliptic pipe and bar with notches, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 73–77.

Shearing stresses of an elliptic pipe and notched bar are obtained by use of Saint Venant's flexure function. The theoretical analysis points out that the stress distribution is not influenced by the presence of a crack and that the stress concentration does not occur for vertical cracks. If the crack is horizontal, the stress concentration increases with both the sharpness and depth of the crack. C. B. Matthews, USA

3354. Winter, H., Optimum involute gearing. Study and comparison of various tooth systems [Die Trägfahigste Evolventen-Geradverazhnung. Untersuchung und Vergleich verschiedener Verzahnungssysteme] (edited by Niemann, G.) (Schriftenreihe Antriebstechnik, H. 15), Braunschweig, Friedr. Vieweg & Sohn, 1954, 99 pp., 142 pp. of figs., diagrams. DM 17.80.

Book is a thorough concise treatise of unequal addendum gearing. The first of the three major subdivisions contains a discussion of the characteristics and relative advantages of over twenty involute tooth systems, as well as a chapter analyzing the basic criteria for comparing tooth forms under various forms of modification systems. On the basis of the primary criteria, (1) surface endurance limit, (2) bending strength, (3) wear, and (4) velocity of sliding, as well as several secondary criteria, optimum tooth modifications are derived, using interchangeable sets or special meshes. In certain cases, the modified (unequal addendum) tooth form is shown to give over 200% improvement.

The second portion consists of a tabulation of equations for obtaining gear-mesh characteristics from given design parameters.

The third portion of the book discusses in detail the influence of the significant gear parameters on surface endurance and beam strength and on wear and sliding velocity, for several standard tooth systems. The discussion is accompanied by over 100 design charts presenting the results in curve form. The book concludes with 62 bibliographical references to German and English books, articles, and standards.

Readers not fully familiar with German gearing nomenclature may wish to consult H. Trier, "Die Zahnformen der Zahnräder" [AMR **7**, Rev. 3508]. G. A. Nothmann, USA

3355. Cohen, M. J., The design of the expanding-shoe friction clutch, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-86, 15 pp.

A complete and exact treatment of the problem of the design of friction clutches of the expanding shoe-variety is given. The method followed is one which, *ab initio*, takes all the relevant parameters of the clutch, such as dimensions, elastic properties, and the forces-moment systems to be arbitrary and then proceeds to relate them by a set of equations that illustrate the final equilibrium of the system. From the three basic equations derived, a simple and very rapid design technique is evolved which can be used reliably by technicians for the design of one such clutch to transmit a required torque. Section 4 incorporates the complete technique of design and can be interpreted simply without reference to the theoretical considerations leading to it in the preceding sections. From author's summary

Plates, Disks, Shells, Membranes

(See also Revs. 3310, 3329, 3333, 3338, 3344, 3353, 3374, 3375, 3376, 3377, 3379, 3380, 3381, 3388, 3485, 3566)

3356. Galletly, G. D., Influence coefficients for hemispherical shells with small openings at the vertex, *J. appl. Mech.* **22**, 1, 20–24, Mar. 1955.

A thin hemispherical shell of constant thickness is considered, which is subjected to shearing and bending forces at the boundary of its opening. The interesting influence coefficients are determined by three methods. For all cases where the central angle of the opening is less than 30 deg, the second method, using the approximation $\cot v = 1/v$, is preferred.

H. Neuber, Germany

3357. Strauss, E. E., Simplified calculation of long self-supporting shells (in French), *Bull. tech. Suisse Rom.* **80**, 17, 18; 261–268, 277–281, Aug., Sept. 1954.

Formulas and graphs are presented for principal inner stresses in a cylindrical shell, with a uniformly distributed surface load, resting on localized supports situated at the extremities of the cylindrical elements. Multiple arches connected on edges are considered as well as detached single arches. Based upon a method of Lundgren, the customary simplifying assumptions are made, including zero plate moments and zero transverse contraction. It is concluded for long arches that the height is proportional to the square of the distance between supports and to the load, is inversely proportional to the normal admissible constraint, and is independent of the width of the arc.

The investigation of the question whether a circle constitutes the best form for the shell directrix shows that the so-called arch stresses depend on the curve of the edge. The necessity of using a directrix of different edge curvature than a circle is decided by means of included graphs.

Integration leads to elliptical integrals, but this complication is avoided by a change of variable which leads to nominal error for an elliptical directrix.

Confidence in the analytic method is established by tests on a

model. Results are in reasonable agreement. A complete numerical example is included. E. A. Trabant, USA

3358. Mikeladze, M. Š., On the bearing capacity of initially anisotropic shells (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **98**, 921–923, 1954.

Forces in an orthotropic shell element are found in terms of the extension and curvature rates for the special cases $\epsilon_{12} = \kappa_2 = 0$ and $\kappa_{12} = \epsilon_2 = 0$. The analysis is based on the strain increment relations analogous to those of Levy-Mises for an isotropic material [R. Hill, *Proc. roy. Soc. Lond.* (A) **193**, 281–297, 1948; AMR **1**, Rev. 1121] and the usual Kirchhoff postulates.

R. M. Haythornthwaite, USA

3359. Beaton, W. C., and Taxter, P. A., Economic aspects of shell-and-tube-exchanger design, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-128, 8 pp.

3360. Bergman, E. O., The design of vertical pressure vessels subjected to applied forces, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-104, 11 pp.

3361. Matumoto, T., The stress distribution in a ring press-fitted outside of a circular disk, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 83–86.

Problem dealt with is that of shrink fit assembly of disk and ring acted on by equal and opposite concentrated loads, one acting at center of disk and the other on periphery of ring. Stress functions for disk and ring are found in series form and effect of concentrated loads on radial shrink pressure is calculated, assuming no friction at interface. Numerical results are presented for different ratios of radii and Young's moduli.

N. C. Dahl, USA

3362. Shinomiya, T., Solution of arbitrary plate by "influence-surface-method," *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 125–130.

Author's introduction says paper describes "a kind of finite-difference method, in which a concentrated load is applied one by one to every nodal point of a net drawn on a plate, and the solution of each case is utilized simultaneously to analyze that plate or related ones."

Author does not introduce basic theory or governing equations, but commences in the middle of problem with a general symbolic matrix formulation, representing a stage reached following matrix manipulation of, and finite-difference substitution in, classic plate equation. Full details are given in Saibel [*J. Franklin Inst.* **234**, 6, 535–547, Dec. 1942].

Paper is essentially in two parts. First concerns inversion of stiffness matrix. Author quotes, but does not use, a seemingly incorrect inversion iteration formula, then quotes, without proof, a seemingly correct, more rapidly converging formula. Author then indicates an experimental method for obtaining a starting approximation for the inversion process.

Second part concerns applications. Author indicates methods of applying and extending known results to plates of other configurations.

Throughout, examples and techniques are indicated but not discussed in detail. Paper is brief to the point of being obscure, and may be a summary of a more lengthy but unquoted paper.

F. S. Shaw, Australia

3363. McKenzie, K. I., and Rothman, M., Note on the bending of a finite rectangular plate under continuous nonnormal loading, *J. roy. aero. Soc.* **59**, 531, 225–227, Mar. 1955.

3364. Sekiya, T., and Saito, A., Bending of sectorial plates under a concentrated load (in Japanese), *Trans. Japan Soc. mech. Engrs.* **21**, 103, 231–236, 1955.

This paper treats the bending of sectorial plates under a concentrated load in the following cases:

(1) Central angle = (π/n) and: (a) the circular edge is clamped, and two straight edges are simply supported; (b) all edges are simply supported; (c) all edges are clamped; (d) the circular edge is freely supported and two straight edges are clamped.

(2) Central angle = $(\pi/2n)$ and: (e) the circular edge is clamped, one of the straight edges is clamped, and the other is simply supported; (f) the circular edge is simply supported, one of the straight edges is clamped, and the other is simply supported. From authors' summary

3365. Koiter, W. T., and Alblas, J. B., On the bending of cantilever, rectangular plates. III, *Proc. k. Ned. Akad. Wet.* (B) **57**, 5, 549–557, Nov./Dec. 1954.

Two solutions to the problem of the semi-infinite strip, discussed in part I of this paper [AMR **8**, Rev. 611], are obtained by (1) an expansion in eigenfunctions and (2) Fourier transforms. The semi-infinite strip is loaded by an equilibrium system of bending moments and shear forces along its root section in such a way that the anticlastic curvature at this section, due to a primary solution for the plate considered as a beam, is compensated. A comparison of the two solutions shows the method of Fourier transforms yields a higher degree of accuracy. A detailed discussion of the numerical results will appear in part IV of this paper. R. E. Heninger, USA

3366. Isida, M., On the bending of an infinite strip with an eccentric circular hole, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 57–60.

Author has proposed a method of stress analysis on problems of an infinite strip containing a circular hole perforated with arbitrary eccentricity from the neutral axis of the strip. In the present paper author develops the analysis only briefly, referring to papers still to be published. Without these papers his method cannot be verified in all details; it seems to be an extension of Howland's method which treated the case of an infinite strip with a circular hole equidistant from both straight edges, i.e., a special case of author's problem [R. C. J. Howland, *Phil. Trans. roy. Soc. Lond.* (A) **229**, 49–86, Dec. 1930, and (A) **232**, 155–222, Apr. 1934].

The maximum stress at the rim of the hole and the stress at the straight edge are shown in diagrams. Author's curve unexpectedly agrees with that found experimentally by photoelastic analysis [M. Nisida, *Rep. Sci. Res. Inst. Japan* **28**, 1, p. 30, 1952, in Japanese]. (Compare discrepancies formerly found by Howland in the neighborhood of a boundary.)

The paper is a valuable contribution to problems of perforated plates. E. Seydel, Germany

3367. Ugodchikov, A. G., Determination of stresses in a plate with several circular holes plugged with press fitted disks, if the contour of the plate is that of Pascal's limaçon (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **17**, 203–206, 1953.

Author uses method of Muskhelishvili, and treats the plate as a single or multiple connected region depending upon the number of holes. The solution is given for cases when the plate is stressed

either due to a load at the boundary or to the pressure exerted by disks. The maximum stresses are not only, as usually, at the outer boundary of the holes, but also at the concave side of the limaçon.

M. Maletz, USA

3368. Lehnickiĭ, S. G., An approximate method of determination of the stresses in an elastic anisotropic plate near an opening differing little from a circle (in Russian), *Inzhener. Sbornik Akad. Nauk SSSR* **17,** 3–28, 1953.

Author uses conformal mapping and power series to find approximately stress distributions around holes mapped onto the unit circle by functions of the type

$$z = a\left\{\zeta + \epsilon \sum_{n=1}^{N} (\alpha_n + i\beta_n)\zeta^{-n}\right\}$$

Instead of one boundary-value problem for the unit circle, he obtains two boundary-value problems for "unit ellipses," resulting from affine transformations of the unit circle. These transformations arise from the use of three complex variables

$$z = x + iy, \quad z_1 = z + \lambda_1\bar{z}, \quad z_2 = z + \lambda_2\bar{z}$$

where λ_1, λ_2 are determined from the generalized biharmonic equation governing the plane problems of anisotropic elasticity. Several cases of almost square holes (with four axes of symmetry) under different external loading conditions are treated in detail and numerical results illustrating the method are given.

J. R. M. Radok, Australia

3369. Kalandiya, A. I., On the problem of equilibrium of an elastic plate with supported boundaries (in Russian), *Akad. Nauk Gruzin. SSR Trudi Tbiliss, Mat. Inst. Razmadze* **19,** 193–210, 1953.

Author extends work by Halilov [*Prikl. Mat. Mekh.* **14,** 405–414, 1950] to multiply connected regions. Under the same general assumptions, referring to the boundaries and the types of solutions sought, the existence of solutions is proved by reduction of the problem to a system of singular integral equations.

J. R. M. Radok, Australia

3370. Hart, V. G., Equilibrium of membranes elastically supported at the edges (Note), *Quart. appl. Math.* **12,** 4, 408–412, Jan. 1955.

The boundary-value problem for small statical deflections of a membrane loaded by a uniform pressure is solved for particular cases in which the membrane is elastically supported along its edges. The edge is restrained at any point by a force proportional to the displacement at that point.

A transformation reduces the problem to one of solving the Laplace equation with mixed boundary conditions. Solutions are given for an equilateral triangular membrane and for a rectangular membrane. In each case the total potential energy of the membrane and the support is given.

M. L. Baron, USA

3371. Udoguchi, T., Stresses in a rotating disk with insertions in its eccentric holes, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 67–72.

The actual problem seems to be the design of ultracentrifuge rotors and similar devices. In a former publication [AMR **4,** Rev. 2862] author arrived at the results for the stresses in a rotating disk containing an eccentric circular hole. In the present treatment the effect of inserts on the inner surfaces of the hole is considered. It is assumed that the presence of the inserts is equivalent to a normal pressure on the inner surface of the hole. This normal pressure is approximated by

$$\sigma_{\alpha_1} = (P/2)\left[\cos\theta - \frac{3}{4}\cos^2\theta - \frac{1}{4}\right]$$

where θ is the angle between the positive y-axis and the radius of the hole.

Using generalized plane elasticity and bipolar coordinates, stress functions are found to satisfy the boundary conditions imposed by σ_{α_1}. The stresses so obtained are added to those given in the cited publication to give the stresses for the complete problem.

Y.-H. Pao, USA

Buckling Problems

(See also Revs. 3309, 3381, 3382)

3372. Jäger, K., Design of slender reinforced-concrete columns loaded eccentrically (in German), *Beton u. Stahlbeton.* **50,** 3, 75–79, Mar. 1955.

In conformity with German and Austrian regulations (DIN 1045; ÖNORM B 4200, 4 Teil), the design theory of eccentrically loaded columns of reinforced concrete neglects entirely the deflections (Theorie I. Ordnung), requiring only an additional verification of buckling conditions considering the load as axial. Author shows how those prescriptions, in unfavorable cases, may result in an unexpectedly high reduction of real safety factor; the problem is not of allowable stresses, but one of stability. As a complement to chap. 5 of his well-known book "Festigkeitsnachweiss im Stahlbetonbau" [Wien, Manzsche Verlagsbuchhandlung, 1948], Prof. Jäger states the possibility of simplifying the problem, rigorously very complex, of critical load determination considering column deflections (Theorie II. Ordnung) and real properties of materials (Limit design—Traglastverfahren), presenting, to facilitate numerical computations, a very simple table, applicable with reasonable accuracy to most diversified conditions of eccentricity, slenderness ratio, quality of steel, characteristics of concrete, reinforcement percentage, and cross-section form.

I. Wolff, Brazil

3373. Heckeroth, H., Buckling of two columns supporting each other (in German), *Stahlbau* **23,** 10, 242–245, Oct. 1954.

Author studies the particular case of buckling of two bars placed in conical form, hinged at their vertex, joined inwardly by another bar also hinged and placed at any distance from either of the supports, and the supports of the whole also hinged. Symmetry of form is supposed.

Author bases his work on Ratzerdorfer's general solutions and on Chwalla's work. After giving the relation between angular deformations and extreme moments, he considers the shape of the structure after reaching critical load, and the transcendental buckling condition is obtained; simplifications then permit determination of the comparative length of buckling. This length finally allows verifying the elastic stability and stresses according to German regulations. One table allows the quick calculation of the mentioned length. Two examples, one for wooden structure and another for steel, clear up the application of method.

The case studied is seen in some types of roof framework.

A. M. Guzmán, Argentina

3374. Kirste, L., Deformation of a thin circular cylinder into a developable surface (in German), *Öst. Ing.-Arch.* **8,** 2/3, 149–151, 1954.

The critical axial compressive load for a circular cylinder is derived under the assumption that its surface buckles sinusoidally

both in the longitudinal and the circumferential directions. In the limit this results in a plastic deformation into a developable surface. The critical stress thus obtained coincides with the stress given by Michielsen [AMR **2**, Rev. 1377] within 4 %. The critical wave length remains undetermined in this derivation, a result agreeing with experiments that show the possibility of different polyhedral deformations in buckling beyond the elastic limit. M. G. Salvadori, USA

3375. Benthem, J. P., On the buckling of rods and plates in the plastic region. Part II (in Dutch), *Nat. LuchtLab. Amsterdam Rap.* S.423, 56 pp., Jan. 1954.

Author wants to investigate whether it is correct to use theory for plastic plate buckling based on deformation theory. Since critical stress of compressed plates depends considerably on the derivative $d_\gamma/d\tau$, tables were computed for comparing $d_\gamma/d\tau$ from flow theory and assuming initial eccentricities ($\tau \neq 0$), with $d_\gamma/d\tau$ from deformation theory without eccentricities ($\tau = 0$). It appears that in most cases $d_\gamma/d\tau$ ($\tau \neq 0$) from flow theory is much lower than $d_\gamma/d\tau$ ($\tau = 0$) from deformation theory, so that assumption of flow theory and initial eccentricities would lead to critical stress higher than experimental one. No definite conclusions could be drawn. Reference is made to recent papers by Onat and Drucker [AMR **6**, Rev. 3397) and Bijlaard and Wiseman [AMR **7**, Rev. 1764] on the same subject.

P. P. Bijlaard, USA

3376. Lepik, Yu. R., Stability of a rectangular elastic-plastic plate nonuniformly compressed in one direction (in Russian), *Inzhener Sbornik, Akad. Nauk. SSSR* **18**, 161–164, 1954.

The title problem is treated for simply supported plates. The analysis only differs from that for elastic plates through the use of plastic moduli. Numerical results for a range of plate aspect ratios are given for the case when the applied end load varies linearly from zero across the plate width. These results are computed for plate material with specified values of the plastic moduli. The results need careful interpretation in view of recent work [E. T. Onat and D. C. Drucker, AMR **6**, Rev. 3397] illuminating the complex behavior of plastic systems at instability.

H. G. Hopkins, England

3377. Popov, S. M., Stability beyond the elastic limit of rectangular plates with off-center tension or compression (in Russian), *Inzhener Sbornik, Akad. Nauk. SSSR* **18**, 165–173, 1954.

The title problem is treated for simply supported plates, numerical results being computed for certain special cases. The analysis is similar to that in the preceding review, and the reviewer's remarks on this latter paper again apply.

H. G. Hopkins, England

Joints and Joining Methods

(See Revs. 3330, 3401)

Structures

(See also Revs. 3343, 3365, 3372, 3373, 3418, 3566, 3570)

3378. Chamecki, S., Influence lines in plane and three-dimensional continuous structures [As linhas de influência nos pórticos contínuos planos e do espaço tridimensional], Rio de Janeiro, Brasil, Editora Científica, 1954, 76 pp., 2 tables.

Method presented, which author calls "displacement propagation process," is a method of successive approximations based on the well-known theorem that an influence line is the deflection curve of the structure under the action of suitable unit distortion at the cross section to be studied. Displacements of the joints of plane or three-dimensional continuous structures are determined and ordinates of influence lines at some cross sections of the members are deduced. Method gives a clear visualization of the physical phenomenon (corresponding to gradual deformation of the structure by successive propagation of rotations and translations) and can be interpreted as the resolution by iteration of the equations which result from the condition that the forces acting at each joint and at each story (rotation of the joint or translation of the story) are equal to zero. As in Cross' method, numerical calculation is made on a scheme of the structure, the results being rapidly convergent and easily checked.

Author presents some tables of numerical values to assist calculation, whatever be the variation of moment of inertia of members, and some well-chosen practical examples.

This method is a valuable and interesting contribution to the theory of continuous structures and differs fundamentally from the Grinter method of balancing angle changes.

F. J. S. Correia de Araujo, Portugal

3379. Roy, M. D., Method of stiffness in the analysis of continuous structures, *J. Instn. Engrs. India* **35**, 2, 233–263, Dec. 1954.

Three methods are compared for the calculation of restraining moments at the ends of a prismatic member in a frame when fixed end moments and stiffnesses are known. Method I derived formulas by noting the sum of an infinite series generated by the moment distribution process. Method II employs joint rotations and carryover angles, while Method III is the Hardy Cross moment-distribution procedure. Method III is judged to be the most advantageous for complex frames from the standpoint of simplicity and convenience. R. B. McCalley, Jr., USA

3380. Tsuboi, Y., Stress analysis of a wall under bending when stiffened around by rigid frame, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 121–123.

Problem of edge-stiffened rectangular plate loaded in bending in its plane through the edge stiffeners is treated as problem in plane elasticity. Author sets up stress function in terms of several sets of coefficients which must be determined from given boundary-condition equations. Expressions, also in terms of these coefficients, are provided for edge slope and stress distributions and stiffener forces and displacements.

Equations contain several minor errors, including a dimensional one in a term of the stress function. Making the most obvious correction to this term, reviewer was unable to check all of author's stress-distribution expressions. C. M. Tyler, Jr., USA

3381. Müller, W., Theory of the four-column mushroom floor (in German), *Ing.-Arch.* **22**, 1, 60–72, 1954.

Author applies methods used in previous articles to the case of a rectangular slab, uniformly loaded, with four symmetrically arranged columns.

In one example the Navier boundary conditions (deflection $w = 0$ and $\Delta w = 0$) are used, the loading first expressed as a double sine series, the deflection deduced, and then reduced to a single series by using known summations. Moments are deduced by using the logarithm of theta functions.

A second example takes the boundary conditions as zero slope and zero shear and starts with a double cosine series for loading.

Contour diagrams of deflection and mean bending moment for a particular example of each case are included.

A. Burn, Australia

3382. Pearson, R. G., The strength of solid timber columns. I, II, *Austral. J. appl. Sci.* **5,** 4, 363–402, Dec. 1954.

In the first part of the paper the results of 465 model timber column tests on four timber species and with varying slenderness ratio and eccentricity are given. Comparison of the test results with theoretical failure loads given in the second part shows a very good agreement for centrally loaded columns with the Engesser-Shanley theory (tangent modulus). For eccentrically loaded columns, a fair agreement can be reached with a modified secant formula. Reviewer believes that a still better agreement is possible with an exact calculation of the failure load, based on the real stress-strain diagram of the timber species.

The tests are a valuable contribution to a better knowledge of the behavior of timber columns with plain cross section.

F. Stüssi, Switzerland

3383. Lusser, E., Timber structure of nailed plate girders (in German), *Holz als Roh- und Werkstoff* **12,** 12, 472–474, Dec. 1954.

The nailed plate girder of 60-ft span with an intermediate support was designed as a timber frame with an intermediate pendulum column. The timber framing was covered on both sides with diagonally arranged 1-in. boards. As many as 120 lb of nails were required per frame. The whole timber structure, completed within two months, was considered the most economical solution under stated conditions. E. G. Stern, USA

3384. Walz, K., and Weil, G., Influence of air void-forming additives upon the strength and dynamical elasticity constant at freezing (in German), *Bauingenieur* **30,** 1, 15–20, Jan. 1955.

3385. Pauw, A., Lightweight aggregates for structural concrete, *Proc. Amer. Soc. civ. Engrs.* **81,** Separ. no. 584, 14 pp., Jan. 1955.

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 3346, 3375, 3376, 3377, 3394, 3410, 3411, 3412, 3413, 3414, 3415, 3418, 3425, 3429, 3430, 3431, 3577)

3386. Bridgman, P. W., Certain aspects of plastic flow under high stresses, "Studies in mathematics and mechanics" (presented to R. von Mises by Friends, Colleagues, and Pupils), Academic Press, Inc., New York, 227–231, 1954.

Brief report on recent experiments on plastic behavior of various materials under high hydrostatic pressure up to 10^5kg/cm^2. Such values are obtained by pressing material in form of thin disks between carboloy blocks. After some initial deformation, an equilibrium thickness of $\sim 10^{-3}$ in. is reached, where most of interior of material is under hydrostatic pressure p because of radially directed frictional forces between material and block surfaces. Investigated is plastic behavior of materials under torsion.

Results: At given rate of twisting ω, mean shearing stress reaches a steady value τ only after rotation angles up to several 100°, equivalent shears of 10^3 to 10^4 radians. To a high degree of approximation τ is independent of ω, indicating that materials behave as ideal plastic bodies. But when direction of twisting is reversed, previous value of τ is only reached after back rotations, of $\sim 10° \cong 25$ rad. Furthermore, τ increases with increasing p, retarded up to $p \sim 5.10^4$ kg/cm^2, but accelerated at higher pressures. This is not in accordance with von Mises yield criterion for ideal plastic bodies. Obtained values $\tau \sim 160$ kg/mm^2 and ~ 32 kg/mm^2 for Cu and NaCl, respectively, at $p = 10^1$ kg/cm^2 approach "theoretical" shearing strength, indicating that dislocation mechanism of gliding is rendered under such conditions.

A. Kochendörfer, Germany

3387. Olszak, W., Foundation of the theory of inhomogeneous elastoplastic bodies (in Polish), *Arch. Mech. stos.* **6,** 493–532, 1954.

Author remarks that the well-known yield criteria and stress-strain relations for ideal isotropic elastic-plastic solids do not require homogeneity of the material. Final results of analysis of a thick cylinder that is nonhomogeneous radially are described; details are promised in part 2. Author contends that deliberate introduction of nonhomogeneity will lead to economies in design.

R. M. Haythornthwaite, USA

3388. Lomakin, V. A., On large elastic-plastic deformations (in Russian), *Vestnik Moskov. Univ. Ser. Fiz.-Mat. Estest. Nauk* **9,** 5, 41–45, 1954.

Paper presents an analysis for the finite deformation of a thick cylinder subject to combinations of internal and external pressure. Plane-strain conditions are assumed and the material is supposed to be incompressible. A total strain-type plastic law is used together with the natural (logarithmic) strain measure. The longitudinal thrust is found for the general case. For the case of internal pressure only, an upper bound is found to the rate of increase of pressure with expansion. This bound is said to have led to accurate prediction of the level of deformation at which instability was observed in an aluminum tube ($b/a = 2$).

R. M. Haythornthwaite, USA

3389. Mirzadzhanzade, A. Kh., and Mirzoyan, A. A., Approximate calculation method for the motion of viscoplastic fluids at the initial part of the conduit (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **96,** 3, 445–448, May 1954.

Authors consider two-dimensional and axisymmetric flows of viscoplastic fluids into pipes. They postulate a "core" of fluid moving with velocity constant across each section and tending to a constant value, surrounded by a boundary layer in which the velocity profile is parabolic. Hence they calculate the length of the "initial section" of the tube, in which the flow is building up to the final steady state, and show its dependence on the Reynolds and Ilyushin numbers and on the ratio of the widths of the tube and core. F. J. Berry, England

3390. Olszak, W., On some problems of the theory of bound elements with regard to the rheological properties of their materials, *Bull. Acad. Polonaise* **2,** 3, 123–130, 1954.

This is a difficult paper to read because there are references to the author's previous work, especially to the one in preparation. No derivation is presented of the basic equations. Assumptions include linear isotropic core of a bound column with creep terms. Body is viscoelastic and creep phenomena are linear for conditions away from the elastic limit. Also, the structure is nonhomogeneous in which the core is liable to creep and the binding is elastic and continuous.

Some of the expressions, such as helical binding, normal bound elements, and "specific" creep function, are not clarified.

No experimental data are presented and author admits some work is needed for verification.

For a composite concrete column, author concludes from theoretical analysis that the lateral pressure due to creep can increase to 180% in the core. H. Majors, Jr., USA

3391. Rovinskiĭ, B. M., and Liuttsau, V. G., Structural modifications in aluminum in stress relaxation (in Russian), *Izv. Akad. Nauk SSSR Otd. tekn. Nauk* no. 11, 1618–1621, Nov. 1953.

Structural changes in metals due to stress relaxation are quite small to be subjected to Roentgenographic analysis. Authors present a special method which determines the number of inter-

ference spots and investigates their character. This is done by x-ray back reflection procedure applied to metals of large crystal composition. Such materials in the unstrained state provide distinct interference spots or reflections. These spots become diffused due to plastic changes in crystallite forms.

Authors describe the experiments and the results, and offer the following conclusions: (1) The number of interference spots on x-ray diagrams for aluminum decreases while specimens are loaded within elastic region. During stress relaxation the number of these spots reappears increasingly. (2) The curve of relative increase of spot numbers is analogous to the curve of stress relaxation. This phenomenon is due to changes in crystallite perfections. (3) After sufficiently completed relaxation, the number of reflections appears to be greater than the original number. Spots of reflections appear to be diffused. Their form and dimensions change. This is due to translations which produce increase in crystallite imperfections and lead to their fracture.

Hence, according to authors, this investigation establishes that the stress relaxation in aluminum at normal temperature is accompanied by slowly progressing irreversible changes of crystallite shapes in the aggregate. V. A. Valey, USA

3392. Green, A. P., A theory of the plastic yielding due to bending of cantilevers and fixed-ended beams. I, *J. Mech. Phys. Solids* **3,** 1–15, 1954.

Author first investigates a uniformly tapering truncated cantilever subjected to a concentrated shear force at the end, under conditions of plane strain. A plastic-rigid material is assumed and velocity fields are found for all values of the parameters except for very short beams. Author then solves the following related problems: uniform cantilever with various weak supports, uniform cantilever under combined axial and shearing loads, and tapering cantilever under conditions of plane stress.

According to limit-analysis theorems, the load determined in each case is an upper bound on the yield-point load. Author acknowledges this but claims it is "unlikely" that the yield-point loads are overestimated. In only one special case is a stress field constructed to verify this conclusion. Reviewer doubts its validity for long cantilevers with little taper, since elementary beam-theory limit analysis furnishes slightly lower upper bounds.

The particular case of a sheared uniform cantilever was previously treated by Onat and Shield [*Brown Univ. tech. Rep.* **A11-103,** 1953], although the author is apparently unaware of this paper. P. G. Hodge, Jr., USA

3393. Matschinski, M., General approximative solution of the plasticity equations in two dimensions (in French), *C. R. Acad. Sci. Paris* **239,** 1348–1350, 1954.

If a perfectly plastic material in plane strain satisfies Tresca's (or Mises', although the author does not mention this) yield condition, the Airy stress function must satisfy the nonlinear relation $(\Phi_{xx} - \Phi_{yy})^2 + 4(\Phi_{xy})^2 = k^2$. Author states that among all linear approximations to $(a^2 + b^2)^{1/2}$, where $a<b$, the function $0.398a + 0.960b$ is the best and uses this to approximate the yield condition. The resulting approximation contains eight possibilities, depending upon the signs of $X_{11} - X_{22}$ and X_{12} and their relative magnitudes. In each case the author can write down the most general stress solution as one containing two arbitrary functions of one variable each. Author applies his approximation to an example involving the initiation of compressive buckling and predicts certain features of the resulting stress distribution. In view of the numerous examples in plane plastic strain which have been solved by other techniques, it is unfortunate that the author did not discuss such an example so that his method could be evaluated both for exactness and for simplicity. P. G. Hodge, Jr., USA

Failure, Mechanics of Solid State

(See also Revs. 3409, 3495, 3510, 3579)

3394. Bishop, J. F. W., A theory of the tensile and compressible textures of face-centered cubic metals, *J. Mech. Phys. Solids* **3, 2,** 130–142, Jan. 1955.

Previous theories relating deformation textures of aggregates to rotations of individual grains have not accounted for the differences in textures in metals with the same structure and glide geometry. Maximum work principle of Bishop and Hill [AMR 5, Rev. 104] is used to determine stress systems required for macroscopic strain. Hence, operative glide systems and rotations of each grain can be determined. Textures are associated with differential strain hardening on latent and active glide systems. For latent glide systems which harden less rapidly than active ones (e.g., certain alloys), least shear magnitudes are maximized. For latent systems which harden more rapidly than active ones, largest shear magnitudes are maximized. Cases are discussed wherein predicted textures tend to correspond with experimentally determined textures.

Reviewer believes this approach supplies a more satisfying rationale of textures (an extension of Taylor, and Calnan and Clews). However, there are metals, such as silver, which are not explained, and the assumption that each grain undergoes the macroscopic strain is not accurate. J. C. Fisher, USA

3395. Roberts, D. K., and Wells, A. A., The velocity of brittle fracture, *Engineering* **178,** 4639, 820–821, Dec. 1954.

In the propagation of Griffith-type cracks, the balance of energy should contain not only the terms relating to available elastic energy and surface tension (with or without the addition due to the plastic work associated with the new surfaces) but also that due to kinetic energy of the material disturbed by the progressing crack. Authors derive the kinetic energy density distribution in a plate containing a propagating central crack, by utilizing a Westergaard solution [*Trans. ASME* **61, A-49,** 1939]. Terminal velocity of freely running brittle crack is calculated to be 38% of elastic wave velocity, which is in good agreement with experimental results cited from literature.

F. Forscher, USA

3396. Sage, A. M., Recent theories on the cause of temper brittleness in steel, *Metal Treatm.* **11,** 109, 463–468, Oct. 1954.

An assessment of the present state of knowledge concerning the cause of temper brittleness is made. Author indicates that temper brittleness can be attributed to grain boundary segregation of certain elements. Characteristics of elements giving rise to temper brittleness are discussed and a tentative explanation is given for the behavior of molybdenum, which causes temper brittleness in the absence of other alloying elements, but reduces the susceptibility in steels containing manganese or chromium.

From author's summary

3397. Bennett, J. A., and Quick, G. W., Mechanical failures of metals in service, *Nat. Bur. Stands. Circ.* 550, 36 pp., Sept. 1954.

For many years the National Bureau of Standards has made examinations of metal parts that have failed in service for evidence bearing on the causes of failure. Thirty-five such cases, representing the most frequently observed types of failures, are described and the factors of design, fabrication, or use contributing to these failures are presented. The characteristics by which the various types of fractures can be recognized are discussed, and recommended precautions that should be observed to reduce mechanical failures of metals in service are included.

From authors' summary

3398. Klingler, L. J., Barnett, W. J., Frohmberg, R. P., and Troiano, A. R., The embrittlement of alloy steel at high strength levels, *Trans. Amer. Soc. Metals* **46,** 1557–1598, 1954.

The embrittlement phenomenon which may occur on tempering quenched steels to high strength levels is a precipitation or aging phenomenon. The tempering characteristics of the steel play a major role in the development of embrittlement.

A structure composed of 100% bainite (low-temperature bainite) is not subject to the same embrittling reaction. Such bainitic structures displayed properties equal or superior to those of tempered martensite at all strength levels. Mixed structures exhibited lower properties.

A definite correlation is shown between the time-temperature relations for the embrittlement of tempered martensite and the nature and sequence of the carbides resulting from the tempering process. The embrittlement is associated with the initial formation of platelet cementite.

It is proposed that the embrittlement arises from localized precipitation of cementite in the prior austenite grain boundaries, which precedes the general precipitation. The localized overaging would then produce a thin ferrite network which embrittles the steel.

From authors' summary by G. V. Smith, USA

3399. Cornet, I., and Grassi, R. C., Fracture of inoculated iron under biaxial stresses, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-47, 3 pp.

3400. Lambert, J. W., A method of deriving residual stress equations, *Proc. Soc. exp. Stress Anal.* **12,** 1, 91–96, 1954.

Author studies theoretically the two simple cases of axisymmetry and antisymmetry of residual stresses. The external surface strains of a hollow cylinder are supposed as measured when layers are bored from its center. The novelty of the paper is shown by the following quotation: "In all cases. . .(previously). . , the strain resulting from the removal of a typical layer is related to the stress existing in that layer and then the stress in this layer is 'corrected' by calculating the amount this stress has changed by removing previous layers. This line of reasoning is not necessary since the total change of strain after removing any number of layers does not particularly depend upon the stress that was in the last layer removed nor on the thickness of the layer but depends only on all the stress that was contained in all the material which has been removed up to this point."

K. H. Swainger, England

3401. Weibull, W., The static strength and the fatigue strength of riveted, spotwelded, and redux-bonded joints in 24S-T aluminum alloy sheet, *SAAB Aircr. Co. Linköping, TN* 31, 12 pp., 1954.

Over 300 butt joints with a backing strip stiffened against bending were tested with repeated tensile loads varying from zero to a maximum. Static joint efficiencies were 70 to 95%, while at 10^6 cycles, about the longest life observed, all joints, except for the redux joint with the narrower overlap, were 45 to 60% efficient.

F. A. McClintock, USA

3402. NACA Subcommittee on Heat-Resisting Materials—NACA Headquarters, Cooperative investigation of relationship between static and fatigue properties of wrought N-155 alloy at elevated temperatures, *NACA TN* 3216, 92 pp., Apr. 1955.

Extensive data are given relating properties of N-155 alloy under static, combined static and dynamic, and completely reversed dynamic stress conditions. Time periods for fracture ranged from 50 to 500 hours at room temperature 1000, 1200, 1350, and 1500 F. The work was on a cooperative basis to help clarify the principles governing load-carrying ability of heat-resistant alloys at temperatures and conditions where both creep and fatigue can occur simultaneously. In view of the uncertainty in interpreting results of various types of fatigue tests, duplicate data were obtained from as many types of fatigue-testing machines as could be arranged.

From author's summary

3403. Fukui, S., Sato, S., and Kitagawa, Y., On the fatigue of work-hardened steel (9th Report) (in Japanese), *Rep. Inst. Sci. Technol. Tokyo* **8,** 6, 265–270, Dec. 1954.

3404. Clarebrough, L. M., Hargreaves, M. E., Head, A. K., and West, G. W., Technical Note: Energy stored during fatigue of copper, *J. Metals* **7,** 1, 99–100, Jan. 1955.

3405. Gohn, G. R., Fatigue: the problem and some solutions, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-87, 8 pp.

Material Test Techniques

(See Rev. 3416)

Mechanical Properties of Specific Materials

(See also Revs. 3323, 3337, 3382, 3390, 3391, 3396, 3397, 3401, 3402, 3426, 3432, 3519, 3520, 3534, 3541, 3576)

3406. Promisel, N. E., Titanium fills need for super material in aircraft of the future, *J. Metals* **7,** 3, 443–448, Mar. 1955.

Paper is of a general nature, but presents an excellent summary of the diversified potentialities of titanium in aircraft. A number of improvements in certain properties, and particularly in their uniformity and reliability, as well as economical progress must be made to permit maximum usage. G. Sachs, USA

3407. Fairbairn, G., North American Aviation Inc. expands use of titanium to airframes, *J. Metals* **7,** 3, 449–452, Mar. 1955.

Paper presents a concise summary of present fabricating techniques for titanium-sheet parts at North American Aviation. Extensive use of moderate heat, special attention to slow forming, stress-relief anneals, use of shims on mismatched parts, etc., are among the measures which have led to the successful application of titanium and titanium-alloy sheet for most of the aft fuselage of a current fighter plane. G. Sachs, USA

3408. Fast, J. D., Notched-bar impact tests on steel (in Spanish), *Cienc. y. Tecn.* **120,** 604, 21–32, 1954.

For judging the strength of steels, the so-called notched-bar impact test is often applied in addition to the usual tensile test. Article deals not only with matters of common knowledge such as the execution and significance of the notched-bar impact test and the elementary concepts of stress and fracture, but also with original measurements by means of which the impact value of pure iron is determined as a function of temperature; the effect thereon of oxygen, carbon, and nitrogen is investigated.

From author's summary

3409. Kornfeld, H., Correlations between the appearance of fracture and the steep slope of the notched bar toughness/temperature curve of soft steels, *Stahl u. Eisen* **74,** 23, 1526–1536, Nov. 1954.

Paper presents statistical analysis on (1) open-hearth fine-grain

steel, (2) rimming open-hearth steel, and (3) Armco ingot iron at a testing temperature of −60 to +40 C. The fracture types are: rupture, mixed fracture, deformation fracture, and their mathematical calculation. The characterization of the steep slope by the temperature of the most frequent occurrence of the mixed fracture is shown. The probability of obtaining safe information by the use of notched-bar impact tests in the steep slope is presented. Derivation of the number of specimens required for the tests are also given. From author's summary

3410. Smith, G. V., and Seens, W. B., Short-time tension and creep-rupture properties of hardened 1040, 4340, and Ni-Cr-Mo-V steels up to 1000 F, *Proc. ASTM* **54,** 1028–1037, 1954.

3411. Heger, J. J., Hodge, J. M., and Marshall, P. W., Effect of microstructure on the elevated-temperature strength of alloy steel, *Proc. ASTM* **54,** 1003–1027, 1954.

3412. Rush, A. I., and Freeman, J. W., Statistical evaluation of the creep-rupture properties of four heat-resistant alloys n sheet form, *Proc. ASTM* **54,** 1098–1128, 1954.

3413. Nelson, K. E., Tensile and creep properties at elevated temperatures of some magnesium-base sand-casting alloys, *Proc. ASTM* **54,** 1081–1097, 1954.

3414. Baker, H., Tensile and creep properties at elevated temperatures of some magnesium-base wrought alloys, *Proc. ASTM* **54,** 1068–1080, 1954.

3415. Richmond, J. C., Moore, D. G., Kirkpatrick, H. B., and Harrison, W. N., Relation between roughness of interface and adherence of porcelain enamel to steel, *NACA Rep.* 1166, 9 pp., 1954.

Supersedes article reviewed in AMR **7,** Rev. 1821.

3416. L'Hermite, R., The shrinkage of hydraulic cements (in French), *Rev. Matér. Constr.* no. 469, 277–284, Oct. 1954.

The shrinkage of hydraulic cements depends on the evaporation of a part of the water added during the mixing. The evaporation occurs according to a law analogous to the quantity of capillary water lacking with regard to the total capacity in capillary water (suction water); it is also proportional to the quantity of cement hydrated. Those properties can be explained by the special structure of hydrated cement.

Shrinkage of concretes depends on shrinkage (in the same hygrometry) of the cement contained in the composition, on dosage, on granular composition. Shrinkage of concrete of which the composition is known can be computed by close approximation.

The fissure test with a ring has been chosen to compute swiftly the comparative danger which a cement may offer with regard to shrinkage and its consequences. For some cements and in particularly severe hardening circumstances, the effects of shrinkage can be mitigated by using protective films, the efficiency of which has to be specified in every case by a special test.

From author's summary

3417. Joisel, A., Deformation and fracture of cement (in French), *Rev. Matér. Constr.* no. 462, 55–67, Mar. 1954.

In the study of the deformation and fracture of cement, it is usually assumed that it is homogeneous and conforms with Hooke's law.

This hypothesis is wrong; and this is why breaks that have been observed do not fall in with theory. For example, areas of break follow the direction of the compression where the strength varies in relation to the dimension and form of the test piece, etc.

The theory outlined takes account of the heterogeneous texture of a pseudo-solid like cement and is based on the following principles: (1) Breaking by compressive stress starts in a shearing effect along the areas formed by the original isostatic lines. (2) An "elementary break" continues to spread, without increase of pressure, right to the end of the corresponding original isostatic lines. (3) The "total break" occurs when the specific breaking area attains a certain extent, dependent on the type of cement, and the way in which compression is exerted.

Some applications of the theory are given.

From author's summary

3418. Ahu, J., Resistance of bituminous pavements and joint fillers in airport runways against blast of burnt gas under jet operations (in French), *Ann. Ponts Chauss.* **124,** 5, 521–537, Sept./Oct. 1954.

Conventional bituminous pavements and joint fillers in airport runways offer little resistance to the blast of burnt gas under jet operations.

To permit the study of their behavior on samples and to secure antijet materials, the Laboratoire des Ponts et Chaussées made a testing apparatus, consisting mainly of a small blast pipe fed with illuminating gas and compressed air.

The choice of an adequate rate of combustion (controlled by the feed pressures of air and gas) results in a jet of burnt gas at some distance away from the mouth of the blast pipe which has temperature and speed conditions approaching the real ones, so that a very satisfactory correlation between the effects produced by the apparatus and those of the jet aircraft may be observed.

Some considerations of a general order on the behavior of pavements and joint fillers conclude the report.

From author's summary

Mechanics of Forming and Cutting

(See also Revs. 3308, 3330, 3498)

3419. Métral, A. R., edited by, Machine tool. Vol. VI. Machining by abrasion [La machine-outil. T. VI. Usinage par abrasion], Paris, Dunod, 1954, 168 pp.

The reviewed textbook is a symposium, worked out according to a well-coordinated program. Its general trend is to give its reader, most probably an engineering student, a technician, a production engineer, or a technical salesman, a very good idea about grinding wheels, grinding machines, and grinding techniques. The particular chapters discuss: (1) Grinding wheels (R. Lauroua and M. Teyssedre); (2) Diamonds and wheel dressing (A. Wolff); (3) Production grinding machines (S. Adamowicz); (4) Honing and lapping (A. Bailly); (5) Sharpening machines and procedures (A. Plu).

The book may be considered as a very general reference book on grinding, but it is not complete. Apart from a lack of sufficient description of grinding principles, there is nothing said about diamond wheels. The recommendations on grinding fluids are very general. Many practical hints and description of possible grinding troubles might be usefully added. There is also lack of bibliographical references.

Of particular interest are the chapters (3) about production grinding, and (4) about honing, very well done and very useful for the machine shop. The book, treating of a certainly rather difficult and not very well-known subject, is an interesting and expressive picture of actual grinding practice in France.

A. Niedzwiedzki, USA

3420. Métral, A. R., edited by, Machine tool. Vol. III. Machining with rotating tools [La machine-outil. T. III. Usinage par outils en rotation], Paris, Dunod, 1954, 432 pp.

This book, volume three of a well-organized series of eight, is an encyclopedical course of design and application of machine tools, working with rotating tools (milling, drilling, reaming, etc.). Its trend is already marked by its editing under the chairmanship of A. R. Métral, President of the Syndical Board of the French Metal-Working Industries, and it constitutes a unique review of French achievements in the reported line. The particular chapters of the book discuss: (1) Design and application of drilling machines (Y. Renard); (2) Design and application of the combined milling and boring machines (B. Gardair); (3) Design and application of milling machines (G. Hure); (4) Machining power units and their successful application (J. Lacroix); (5) Design and application of transfer machines (P. Bezier); and (6) Design and application of jig-borers, jig-millers, and jig-grinders (M. Chalvet).

Although the book is of a rather encyclopedical character, it is of great interest for American readers because it represents a carefully prepared French point of view. Of particular value seem to be chapters reflecting the French experience in construction of drilling machines (I), of transfer machines, as applied in famous Renault Works (V), and in jig borers, as applied for defense production (VI). Throughout the book an effort is evident to report broadly the French achievements and to compare them with the American and German ones. All authors made a considerable effort to present an analysis of subject discussed; thus the book might serve as a textbook for engineering students. Unfortunately, bibliographical references are completely lacking.

The book is of interest to machine-shop builders and to production engineers, especially those interested in mass-production methods.

A. Niedzwiedzki, USA

3421. Vágó, F., Electric spark machining (in Hungarian), *Gép* **7**, 1, 16–24, Jan. 1955.

Author assumes that electric spark material cutting can be regarded as a thermal process, the amount of material separated by the unit of energy depending on the quantity of heat needed for smelting or evaporizing the material and on the value of thermal conductivity. The amount separated from a certain material depends—other data of the circuit being unaltered—on the charging coefficient of the condenser.

At first, solenoids, and later, electrodynamic control gear have been used by the author; the latter one worked well.

The spark cutting machine at the Laboratory of the K. Gottwald, former "Ganz" Electric Co., has been constructed with electrodynamic control, and every grade of machining can be switched on either directly or through a magnet switch by hand control. The accuracy of the tools produced with the spark cutting machine is 0.01 mm. Form fidelity is obtained by small output, surface finish by the use of small-capacity condensers.

Machining of tungsten carbide steel can be accomplished—the separation of material being 0.5–1.0 mm^3/min—with a surface finish of $h_{rms} = 1$ micron.

Author claims that this procedure is also used with excellent results in a special large-scale production.

From author's summary by A. Lenkei, Hungary

3422. Eugene, P., Methods for measuring the efficiency of cutting fluids (in French), *Rev. univ. Min.* (9) **98**, 3, 101–110, Mar. 1955.

Author shows cutting data to determine lubrication effect on tool loss by abrasion and on interfacial temperature related to six conditions: (1) dry; (2) cutting oil and additives, high viscosity; (3) cutting oil and additives, low viscosity; (4) water with 4% soda; (5) water and soluble oil; (6) water. Tool material: high-speed steel with 10% cobalt. Material cut: two steels with 0.037 and 0.018 sulphur and, respectively, 181 and 185 B.H.N.

Results show: interfacial temperature—decreasing as specific heat of cutting fluid increases; increasing as cutting speed increases; higher when cutting dry; lower when using water-base fluids; medium with oil-base fluids. For any given cutting speed, interfacial temperature increases with the feed per revolution. Cutting tool loss due to abrasion increases with cutting speed; is high with water-base fluids; medium in dry cutting and low with oil-base fluids. Author's attempt to relate results to specific work abrasion defined by ratio between frictional work and weight loss of tool per cut leads to difficulties in interpreting results due to simultaneous changes of other variables.

M. Martellotti, USA

3423. Nakhapetian, E. G., Study of the dynamics of Geneva mechanisms used in automatic machine tools (in Russian), *Akad. Nauk SSSR Trudi Sem. Teorii Mash. Mekh.* **14**, 53, 47–67, 1953.

Variations in driving torque and forces in Geneva mechanisms are investigated analytically, and several expressions encountered in the analysis are plotted graphically. Results are given in terms of two parameters: z_k, number of slots in Geneva wheel; and A, ratio of moment of inertia of driven members times square of angular velocity of driving wheel to load torque on Geneva wheel. Oscillograms obtained experimentally from strain gages show qualitative agreement with analytical results, with additional peaks due to dynamical and frictional effects not considered in analysis. Experiments show that undesirable shocks during second half of driving stroke can be reduced by braking action. It is mentioned that frictional effects can be reduced by suitable location of driving elements with relation to Geneva wheel bearings.

T. P. Goodman, USA

3424. Yazawa, S., and Sato, K., On lubrication for steel tube shrinking (I & II) (in Japanese), *J. mech. Lab., Tokyo* **8**, 5, 164–176, Sept. 1954.

The effect of sinking conditions such as the ratio of wall thickness to tube radius, reduction, profile of dies, and sinking speed on the lubrication of steel tube sinking were investigated through authors' previous work on tube sinking.

Thereafter, an experiment was carried out to check the effectiveness of the combination of coatings and lubricants. Electro-welded tubes of soft steel were sunk from their original diameter (31.8 mm) to 27.5 mm at the sinking speed of 9 m/min. The reduction is about 14%. The wall thickness of specimens is 1.4 mm. A sintered tungsten-carbide die is used, and the approach angle is about 12°.

Experiments were carried out with and without coatings. Lime, borax, salt, and phosphate are used for the coatings and machine oil, rape-seed oil, commercial sinking emulsion oil (contains rape-seed oil and rice-bran oil), and commercial metallic soap (prepared to be used with special phosphate coating) are used for the lubricants.

Results are listed in tables. From these, the effectiveness of the combination of phosphate coating and metallic soap and that of the sinking emulsion mixed with pulverized diatomaceous earth and the lubricating ability of the lime coating itself are demonstrated. Borax coating is found not to be appropriate, and the effect of salt coating is supposed to be due to its rusting process.

In part II, the similar combinations of coatings and lubricants are dealt with for a heavier reduction (20% in outside diameter of tube).

The electro-welded tubes of soft steel, original size of outside diameter 25.0 mm and wall thickness 1.4 mm, are sunk to outside diameter 20 mm with a sintered die. As the approach angle is about 25°, the real contact of tube and die takes place at a point near the die exit. The kinds of coatings and lubricants used are listed with their specifications. The combinations and experimental results are tabulated.

From this and the previous reports, borax is found not to be appropriate for steel tube sinking in spite of the fact that it is desirable for wire drawing. This might be due to the difference of the working speeds, with which the temperature of contact surfaces varies widely. Salt coating is appropriate but not recommended for practical use because of its rusting property. The combination of phosphate and metallic soap seems to have been already known.

The investigation of lime coating, and the finding of such materials as diatomaceous earth which can be mixed with the emulsion to increase its effect, are planned next.

From authors' summary

3425. Muranaka, R., Tool-edge temperature and some influential factors on hot-machining (in Japanese), *Trans. Japan Soc. mech. Engrs.* **20,** 98, 645–660, 1954.

The tool-edge temperature consists of temperature both due to plastic deformation on the shear zone and due to tool-chip interface friction. It varies with the work condition, heating temperature, energy on the shear zone and tool-chip interface, fraction of the heat to the chip or the workpiece, and physical properties of the workpiece. The author measured cutting force, chip ratio, contact length of the tool-chip interface, and also the edge temperature for various work conditions and heating temperatures with 0.26% C carbon steel under orthogonal cutting conditions.

Author compares experimental and analytical results. These results may be as follows:

1. The generated edge temperature would be lesser at elevated temperature than at room temperature.
2. The edge temperature would have exponential relation with cutting area, cutting speed, and depth of cut/feed, and exponent value would decrease as heating temperature increased.

From author's summary

3426. Timofeev, V. N., Stresses in the surface layer of steel during grinding (in Russian), *Zh. tekh. Fiz.* **24,** 7, 1273–1281, July 1954.

3427. Guionnet, C., and Papadakis, M., Influence of the size of grinding elements on the size of the product (in French), *Rev. Matér. Constr.* no. 463, 101–107, Mar. 1954.

This investigation was carried out with an intermittent-type laboratory grinder. It has confirmed the fact that extreme fineness can be attained only with small grinding members. The use of large balls leads to the formation of "plaquettes" of very fine particles (overgrinding).

This form of the actual grinding members does not affect the product. From authors' summary

3428. Englesson, T., The grinding technique and its importance for the economical use of carbides in the wood-working industry, *Sven. TraförskInst. Medd.* (52 B), 11 pp., 1953.

3429. Hilbert, H. L., Extruding. Vol. I. Tools [Stanzereitechnik. Bd. I. Schneidende Werkzeuge], 5th rev. ed., München, Carl Hanser Verlag, 1954, 349 pp., 350 figs., 33 tables. DM 19.80.

Book deals with most subjects of cutting; i.e., blanking, piercing, punching, extruding, trimming, etc. (The second and last volume treats drawing processes, i.e., forming, bending, drawing, spinning, coining, etc.) Author starts with useful definitions of terms and symbols, based upon German AWF propositions. Some inconsistencies herein are unavoidable, presumably by history; e.g., author uses the term "Stanzereitechnik" for the whole field of his books, while he defines "stanzen" as the method of forming between punch and die without an essential change of the thickness of the sheet.

The second chapter stresses the necessity of using operation sheets in practical production, tells how to draft them, and gives many examples. The third one covers more than half of the book and treats the design and performance of most types of cutting tools, with many details. The latest developments, also those from the United States and the United Kingdom, are included in this edition. The last three chapters deal with the manufacture of tools, the cutting machine, and the calculation of tools.

A very useful book for beginning technicians in this field who wish to obtain an introduction to the many possibilities of applications, as well as for experienced shop people. Mainly as far as standardization is concerned, several aspects of the text are, of course, bound up with German circumstances.

G. de Witte, Holland

3430. Thomsen, E. G., and Frisch, J., Stresses and strains in cold-extruding 2S-0 aluminum, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-161, 20 pp.

2S-0 aluminum was extruded at room temperature in an inverted extrusion process from a 4.3-in.-diam cylindrical billet into a 1.5-in-diam solid cylindrical bar. Steady-state particle-velocity vectors were determined from gridded, split billets during incremental extrusion steps. These velocity patterns were compared with those obtained previously for lead extrusions having the same billet and die geometry and the same high degree of lubrication; it was found that the patterns for these two metals were identical. The aluminum velocity pattern appeared not to be affected by extrusion load, but the extrusion load was a strong function of the extent of deformation. It was estimated that the extrusion load becomes constant after a reduction of billet length by approximately 2.4-in., the distance the plastic zone of the metal extends upstream from the orifice. The axial-stress distribution in the billet, determined from strain rates and natural strains, taking into account work-hardening, had the same shape as that determined with lead. The wall pressure or radial stress in the plastic zone was found to be lower than the average pressure, but both pressures tend to approach each other beyond the plastic zone. From authors' summary

3431. Wagner, W. S., Plastic working of metals, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-64, 11 pp.

The thermoplastic and crystoplastic states are presented as two distinct ranges of plastic working dependent on temperature. Basic laws governing these phenomena must be delineated. Work-hardening and deformation strength are pointed out with one method of estimating deformation strength from true strain. The effect of aging after plastic working is introduced. The relationship between per cent reduction of area and true strain as measures of the extent of plastic working is presented.

From author's summary

3432. Witthoff, J., Carbide tools for non-cutting uses, *Metal Treatm.* **11,** 109, 456–462, Oct. 1954.

The benefits inherent in the use of sintered carbide tools in noncutting engineering production are discussed. Data are

given on practical experience in this field in Germany, with notes on prospects of future development.

From author's summary

3433. Williams, K. R., and Daniel, S. G., The running-in of engines: choice of cylinder bore finish, *Instn. mech. Engrs.*, 3–10, 1955.

The process of mating of piston rings and cylinder bores in newly assembled diesel and petrol engines is described, and it is shown that an optimum surface finish exists which leads to rapid running-in— or break-in as it is sometimes termed—when either straight mineral or additive-type engine oils are used. In particular it is shown that the running-in of engines fitted with either cast-iron or chromium-plated piston rings may be of short duration when additive-type engine lubricants are used in conjunction with a suitable bore finish. Rig and engine tests are described which demonstrate the influence of surface finish on both the wear and the consumption of oil which occur during the running-in process.

It is suggested that there are two components of surface finish which affect the running-in process. One of these components, the surface undulations of short wave length (surface roughness) influences the rate of wear during break-in, while the surface undulations of longer wave length (surface waviness) determine the amount of wear which must occur before the running-in process is complete. Whatever surface finish is chosen for the cylinder bore, to achieve a break-in which is as rapid as possible it is desirable to eliminate those errors in the machining process which give rise to waviness. From authors' summary

3434. Timms, C., and Scoles, C. A., Automatic indexing machine for measuring gear tooth pitch errors, *Engineer, Lond.* **199,** 5169, 229–231, Feb. 1955.

The need for some form of automatic circular indexing mechanism, capable of dealing with angular increments of any value, such as that of a thirty-nine tooth gear, has long been recognized at the Mechanical Engineering Research Laboratory. This paper describes the successful outcome of development work.

From authors' summary

Hydraulics; Cavitation; Transport

(See also Revs. 3298, 3443, 3445, 3558, 3562, 3563, 3564, 3584, 3585)

3435. Lehnert, Bo, Magneto-hydrodynamics on cosmical and laboratory scale, Thesis for the Doctor's degree at the Royal Institute of Technology, Stockholm, 1955.

After a historical survey, errata, and bibliography, the thesis contains the following papers:

A. On the behavior of an electrically conductive liquid in a magnetic field, *Ark. Fysik* **5,** 5, 69–90, 1952.

B. Experiments on nonlaminar flow of mercury in presence of a magnetic field, *Tellus* **4,** 1, 63–67, 1952.

C. Magneto-hydrodynamic waves in liquid sodium, *Phys. Rev.* **94,** 4, 815–824, May 15, 1954.

D. Magneto-hydrodynamic waves under the action of the Coriolis force, *Astrophysical J.* **119,** 3, 647–654, May 1954.

E. Magneto-hydrodynamic waves under the action of the Coriolis force, II, ibid., no. 2, Mar. 1955.

F. The decay of magneto-turbulence in the presence of a magnetic field and Coriolis force, *Quart. appl. Math.* **12,** 4, 321–341, January 1955.

Magnetic fields are likely to be a common phenomenon in cosmic physics. In 1942 Alfvén discovered the wave motion which exists in an electrically conductive liquid placed in a magnetic field. This discovery marks a new epoch in cosmic physics, and magneto-hydrodynamics is now accepted as a basis for many of the central problems. As for technical applications, it is useful for the design of pumps for electrically conducting fluids (Hartmann, 1937).

The most important experimental investigation (C) in the present thesis from Alfvén's team deals with magneto-hydrodynamical waves in liquid sodium. A circular horizontal copper plate makes rotatory oscillations around its vertical axis near the bottom of a vessel containing liquid sodium. The plate draws the liquid along in the oscillatory motion. The oscillation propagates through the liquid as an internal wave motion up to the free surface, where it is observed. This movement is strongly influenced by an intense magnetic field, 10,000 gauss, with vertical field lines as a consequence of the induced electrical currents in the liquid. The first experiments were carried out in mercury by Lundquist in 1949. Liquid sodium is more interesting from this point of view but very dangerous. Author has the merit of developing the necessary technique.

Having extended the theory as well, author attains an improved agreement between theory and experiments.

In papers D and E, author investigates the influence of rotation on the propagation of magneto-hydrodynamic waves. He finds that rotation entails dispersion, and that plane waves with arbitrary amplitudes are solutions of the differential equations. These not being linear, the sum of two solutions is itself no solution. However, author has derived the condition for a sum to be an approximate solution, i.e., the condition for perturbations to move without great distortion. He finds the influence of rotation on large perturbations to be substantial. This influence should not be overlooked in the theory for the sunspot waves. As a consequence, Alfvén's theory for sunspots should be somewhat modified.

The investigation of the influence of rotation has been extended to a system of random magneto-hydrodynamic waves of small amplitude (paper F), i.e., turbulence. The influence of rotation was earlier considered only for stability problems. Rotation being very common in cosmic physics, the last three papers are fundamental.

Papers A and B describe the influence of a magnetic field on the appearance of a streaming fluid, viz., surface waves disappear, and so on.

The main objections are: Author's hypothesis about the boundary layer is not convincing. He could have won more out of his experimental results if he had paid attention to a famous paper by Taylor about the circulation between rotating cylinders. Author is mistaken about the electrical space-charge in a moving conductor.

Summing up, it is a very good paper. O. H. Faxén, Sweden

3436. Meyer, R., A few recent theoretical results concerning ground water flow (in French), *Houille blanche* **10,** 1, 86–108, Jan./Feb. 1955.

Paper contains the first two chapters of the full publication. Author gives in them the practical results of his study of the validity of Dupuit's hypothesis as applied to ground-water flow.

This study is of the utmost value to the engineer because it enables him to estimate the magnitude of error involved in applying the theory, which is so attractive because of its simplicity.

The cases treated are those resulting from unsteady or periodic flows in their horizontal and dipping strata or beds descending to great depth.

The treatment is lucid; the diagrams delightful; the results are of such importance that the publication of chap. III, giving the theoretical justification, will be eagerly awaited.

A. Gordon-Foster, England

3437. Hall, H. P., An investigation of steady flow toward gravity well, *Houille blanche* **10,** 1, 8–35, Jan./Feb. 1955.

The results of a thorough experimental investigation of the flow pattern around a fully penetrating gravity well are presented. Disadvantages of a sand model are overcome by suitable apparatus and experimental technique. The tests provide valuable confirmation of the applicability of relaxation methods to percolation problems with a free surface. Young's modification of the procedure has been adopted throughout. This doubtless results in simplification but introduces errors which are of importance in the vicinity of the well circumference.

One of the more important conclusions drawn from the results of this paper is the indication of the true significance of the phreatic line. The effect of surface tension is demonstrated, and an empirical equation is given enabling the path of the phreatic line to be determined. The conclusion that the degree of saturation is not a significant factor is rather misleading. In an investigation utilizing uniform material this may be the case, but the author does not comment on the effect of the degree of saturation upon the discharge. A. Gordon-Foster, England

3438. Averianov, S. F., Approximate computation of the capacity of rivers as receivers of drainage systems (in Russian), *Gidrotekh. i Melior.* **7,** 5, 40–52, May 1955.

Method is based on the determination of roughness coefficient from local measurements. Deviation of river reaches from prismatic form is used for corrections to the backwater curves. Water conveyance is computed for a board-full river. Article is of interest for hydraulic engineers. S. Kolupaila, USA

3439. Minnesota International Hydraulics Convention, Proceedings. Part I. Basic relationship of sediment transportation by flowing water, Inter. Assn. Hydr. Res., Hydraulics Div. Amer. Soc. civ. Engrs.; Univ. Minn., Minneapolis, Minn., Sept. 1953, 7–169.

A series of papers presents excellent basic data and analyses of the transport of sediment by flowing water. The papers include the motion of discrete particles along a turbulent stream; studies of critical tractive forces in the movement of bed materials; stability of canals in granular materials; grain-size distribution of bed load in rivers; dredge fill closure of the Missouri River at Fort Randall; regime theory equations applied to a tidal river estuary; transportation of solids in pipes, and others. The papers and accompanying bibliographies are recommended to the student of sediment transport for careful reading.

M. C. Boyer, USA

3440. Khalturin, N. V., Flow under a plane gate in a pressure gallery and pressure on the gate (in Russian), *Gidrotekh. Stroit.* **23,** 7, 36–40, July 1954.

Report contains results of experiments on model rectangular lift-gates in a pressure gallery (12 × 12 cm). For proportionate gate openings (0.1–0.9), head loss coefficients, minimum pressure downstream of the gate, downpull force, and distribution of pressures on gate bottom are given. Relative values are used without indication of absolute magnitudes or their range.

The gates had plane bottom surfaces with slopes of 60°, 40°, and 20° with the horizontal in direction of flow.

Experimental results are compared with those of some empirical and theoretical formulas. I. J. Moskvitinoff, USA

3441. Preston, J. H., A simple approach to the theory of secondary flows, *Aero. Quart.* **5,** part 3, 218–234, Sept. 1954.

The problem of secondary flow is considered which arises when a nonuniform stream is turned. For a constant deflection produced from a continuous vortex filament, no trailing vorticity is set up in the exit flow. In the case of cascade blades with finite dimensions and constant turning, the trailing vorticity is analyzed in several parts giving together no net circulation. The formulas are in connection with Squire and Winter's theory [AMR **4,** Rev. 3672] and with Hawthorne's results [AMR 4, Rev. 3607].

In agreement with Traupel's consideration [AMR **7,** Rev. 1922], it can be inferred from this result that there is no secondary motion for sufficiently large distance downstream from the cascade exit plane. N. Scholz, Germany

3442. Nigam, S. D., and Chatterji, P. P., Hydrodynamical equations for the motion of bodies of revolution in non-viscous rotating liquid, *Quart. J. Mech. appl. Math.* **7,** part 4, 458–461, Dec. 1954.

The nonlinear hydrodynamical equations for the steady axisymmetric flow of perfect fluid have been reduced to one linear differential equation for Stokes' stream function. It is shown that uniform motion of bodies of revolution along the axis of the rotating liquid can be discussed on the basis of this equation.

From authors' summary by M. J. Goglia, USA

Incompressible Flow: Laminar; Viscous

(See also Revs. 3265, 3316, 3317, 3435, 3438, 3440, 3441, 3442, 3466, 3467, 3469, 3472, 3475, 3476, 3479, 3480, 3488, 3500, 3501, 3537, 3589, 3584, 3585)

3443. Starkey, T. V., The laminar flow of suspensions in tubes, *Brit. J. appl. Phys.* **6,** 1, 34–37, Jan. 1955.

An analysis of the flow of a suspension or macromolecular solution in a tube, based on the conception of viscosity as action per unit volume, is given. In the flow mechanism, the suspended particles or molecules form the nuclei of postulated vortexes. This mechanism is used as a basis for the derivation of a relationship between the specific viscosity of the suspension and the linear dimensions of the vortexes. The laws of Einstein, Staudinger, Huggins, and their co-workers are derived simply and as special cases of this relationship.

The law assumes the form $\eta_{sp} = an + bn^2$, where a and b are constants and η_{sp} and n are, respectively, the specific viscosity and molecular concentration of the solution. It is shown to be in good agreement with typical experimental results. The effect of the aspect ratio of the suspended particles or molecules is also considered and it is shown that the longest particle dimension rotates in a plane normal to the vortex axis.

From author's summary by J. A. Businger, Holland

3444. Hogner, E., Influence of edges on the boundary layer (in French), "Mémoires sur la mécaniques des fluides," *Publ. sci. tech. Min. Air, Paris,* 129–134, 1954.

Problem considered is that of laminar flow past a thin finite rectangular plate submerged in a viscous, incompressible fluid. Velocity at infinity is uniform and in the direction of the longitudinal axis of the plate. The hydrodynamic equations are linearized in the manner of Oseen. Integral equations are employed and, with certain approximations, solved. In the central region of the plate the viscous stress is about 70% larger than that found by Blasius. Near the longitudinal edges the stress is approximately double that in the central region. The stress exactly at the edge is not obtained. Author suggests that the effect of the longitudinal edge on the viscous stress is perhaps responsible for the exceptionally large values of drag noticed in experiments with thin-keeled models. Howarth [AMR **3,** Rev.

1973] has attacked similar problem of quarter-plane plate with longitudinal edge parallel to the velocity of flow.

R. M. Meacham, USA

3445. Biesel, F., Mathematical interpretation of "Nikuradse's Harp" from some physical hypotheses (in French), *Houille blanche* **9**, no. A, 255–265, May 1954.

Basic hypotheses: The various sections of the flow are governed either by a laminar law or by a turbulent law, both of which are distinguished by the relation between the velocity gradient and the shearing stress. Criterion for the delimitation of areas in which these laws can be applied are outlined. In the case of smooth pipes, nonconformity is found at low Reynolds numbers, and an attempt at adjustment from plausible physical hypotheses is made. Indeterminateness of the passage to the laminar flow curve and validity of the Blasius straight line for high Reynolds numbers are discussed. Case of rough pipes which are compared to a fictitious smooth pipe is outlined. Differences between curves found and Nikuradse's harp and their possible significance are explored. From author's summary

3446. Strang, J. A., Incompressible flow near a solid boundary, *Comm. Fac. Sci. Univ. Ankara* (*A*) no. 6, 51–76, 1954.

Paper concerns the reasons for the failure of boundary-layer theory in the neighborhood of separation and possible solutions. In reviewer's opinion, the reasons offered are irrelevant. The solutions given are formal and, in certain respects, incomplete. It is believed that, up to now, Dean's solution of the problem [AMR **4**, Rev. 3928] is most appropriate. Y. H. Kuo, USA

3447. Dean, W. R., On the steady motion of a viscous liquid past a flat plate, *Mathematika* **1**, 143–156, 1954.

By calculating the nonlinear terms of the Navier-Stokes equations from the Blasius boundary-layer solution ψ_1, the author found a second approximation ψ_2 by solving a linear inhomogeneous fourth-order partial differential equation. This solution is finally reduced to a sum of two definite integrals and the Blasius solution. Numerical results show that the ratio ψ_2/ψ_1 is everywhere greater than 1 and reaches the highest value of about 1.2 in the neighborhood of the leading edge. Y. H. Kuo, USA

3448. Kornfeld, M., How does a soap bubble burst? (in Russian), *Zh. tekh. Fiz.* **24**, 8, p. 1520, Aug. 1954.

Compressible Flow, Gas Dynamics

(See also Revs. 3265, 3478, 3484, 3505, 3507, 3508)

3449. Woods, L. C., Compressible subsonic flow in two-dimensional channels with mixed boundary conditions, *Quart. J. Mech. appl. Math.* **7**, part 3, 262–282, Sept. 1954.

Equations are given for the calculation of the subsonic compressible flow in two-dimensional channels (by "channels" here is meant any simply connected region of flow bounded by two streamlines, one of which can be at infinity) when the boundary conditions are "simply mixed," i.e., when the pressures are known over some contiguous (if necessary, via the point at infinity) sections of the walls or bounding streamlines, and the shape of the remaining sections is assigned. Solutions to simple problems of this type in incompressible flow are occasionally met in the literature on fluid dynamics. The method of solution is almost invariably based on an application of the Schwarz-Christoffel theorem on the conformal mapping of a polygon, an approach which is limited to problems in which the boundary conditions are specified as step functions.

The general solution obtained in this paper includes as trivial examples many of the solutions obtained by separate and often lengthy applications of the Schwarz-Christoffel theorem and, more important, provides a method of dealing with compressible subsonic flow past continuously curved walls. In this latter case the solution is given by an integral equation, which can be solved by a rapidly converging iterative process.

Five examples are solved in section 5, namely, (1) the flow of a jet deflected round a given curved surface (the Coanda effect); (2) the design of a bend in a channel; (3) the flow of a stream up a step, with boundary-layer separation; (4) Helmholtz flow of a jet impinging normally on a flat plate; (5) a generalization of Borda's mouthpiece.

From author's summary by C. C. Chang, USA

3450. Sekerzh-Zen'kovich, Ya. I., Problem for subsonic rotary flow around a circular cylinder (in Russian), *Prikl. Mat. Mekh.* **18**, 4, 399–408, July/Aug. 1954.

Solution of Legendre potential equation is asked for, as a power series of τ_∞^2 (τ_∞ = velocity at infinity/limiting velocity), instead of more common M_∞^2. Research of successive approximations is presented in complex form. Zero-th approximation is classical for incompressible flow. Singularities of successive approximations are determined; each approximation may then be calculated as a sum of a term expressing singularities and another to take into account boundary conditions.

Actually, formal solution is presented for first approximation. No convergence proof is discussed, nor are results compared with those already known [AMR **2**, Rev. 91].

G. Moretti, Argentina

3451. Mackie, A. G., and Pack, D. C., Transonic flow past finite wedges, *J. rat. Mech. Analysis* **4**, 1, 177–199, 1955.

An approximate solution to the finite wedge is obtained using the exact hodograph equations but disregarding the supersonic boundary conditions. (Essentially Cole's solution with the exception of the use of the exact differential equation.) The influence of disregarding the supersonic boundary condition cannot be assessed, of course, without knowing the exact solution. The result of Trilling and Walker, who improve Cole's result to the extent of fulfilling the condition at the shoulder, appears to be in error, so that their result cannot be used in part for this purpose. The effect of the nonfulfillment of the condition at the shoulder propagates directly through the supersonic region, and the pressures along the sloping wedge surface are thus not "protected" by the supersonic region. H. Yoshihara, USA

3452. von Mises, R., Discussion on transonic flow, *Comm. pure appl. Math.* **7**, 1, 145–148, Feb. 1954.

Author discusses the existence or nonexistence of an analytic or nonanalytic solution of the differential equations of a two-dimensional steady flow of an elastic, nonviscous and nonheat-conducting fluid. Moreover, two boundary conditions must be fulfilled for the velocity of flow; at infinity it must be constant and is given as subsonic flow, and at a given convex contour it must be tangent to this contour. F. Kuene, Germany

3453. Vincenti, W. G., and Wagoner, C. B., Theoretical study of the transonic lift of a double-wedge profile with detached bow wave, *NACA Rep.* 1180, 24 pp., 1954.

Supersedes article reviewed in AMR **6**, Rev. 2303.

3454. Kaplan, C., On transonic flow past a wave-shaped wall, *NACA Rep.* 1149, 12 pp., 1953.

Supersedes article reviewed in AMR **6**, Rev. 1969.

3455. Imai, I., The second-order thin airfoil theory for compressible flow, *J. aero. Sci.* **22,** 4, 270–271, Apr. 1955.

Recently [AMR **8,** Rev. 1421] Van Dyke presented a rule giving the second-order subsonic pressure distribution over a thin two-dimensional airfoil in terms of the incompressible pressures. Present paper gives the general formulas expressing velocity and pressure distributions directly in terms of the shape of the airfoil. The flows for zero angle of attack over an elliptic cylinder and Kaplan's profile are considered as examples. The results agree with those given by Van Dyke and Kaplan [*NACA Rep.* 768], respectively. D. W. Holder, England

3456. Gorgui, M. A., The effect of delta vanes on supersonic wings, *Aero. Quart.* **5,** 251–279, 1954.

This is an application of cone-field theory to the problem of delta-shaped end plates on a rectangular wing in supersonic flow. The analysis follows the lines of the particular version of cone-field theory given by Goldstein and Ward [AMR **4,** Rev. 803]. It is shown that, depending on the thickness and aspect ratio of the end plates, the gain in lift may on balance be more important than the increase of (wave) drag due to the presence of the plates. It would be interesting to compare the results obtained under supersonic conditions with the corresponding effect for low-speed flow. A. Robinson, Canada

3457. Hayes, W. D., Second-order pressure law for two-dimensional compressible flow, *J. aero. Sci.* **22,** 4, 284–286, Apr. 1955.

Note in Readers' Forum.

3458. Woods, L. C., Two-dimensional flow of a compressible fluid past given curved obstacles with infinite wakes, *Proc. roy. Soc. Lond.* (*A*) **227,** 1170, 367–386, Jan. 1955.

The wake behind an obstacle in compressible subsonic flow is allowed to have a varying pressure along its free boundary. The streamlines bounding the wake are computed for a source-type velocity distribution in the wake [$(q/u)-1$ proportional to $1/x$] behind a circular cylinder. The author uses the experimental value of base pressure to fix the proportionality constant and then computes the points at which the wake should separate from the cylinder, obtaining agreement with experimental data (Fage and Falkner). Even for this simple type of wake velocity distribution, the flow field outside of the wake is determined by an integral equation which must be solved by iteration. Tables of coefficients are given which simplify this process; nevertheless, the most important contribution of this paper lies in the mathematical description of the connection between flow separation and wake pressure rather than the numerical application. A similar treatment of the wake problem was given recently by Roshko [*J. aero. Sci.*, Feb. 1955]. He chose a step function in velocity, however, instead of the source function.

L. H. Schindel, USA

3459. Grib, A. A., and Ryabinin, A. G., On the question of the approximate integration of the equations of plane steady supersonic gas motion, *Doklady Akad. Nauk SSSR* (*N.S.*) **100,** 3, 425–428, 1955. (Translation by M. D. Friedman, 2 Pine St., W. Concord, Mass.)

In former works the gas dynamic equations are reduced to the Euler-Darboux equations by a suitable approximation to the coefficients. Either the velocity potential or the stream function or the Legendre potential is taken as the desired function of the characteristic coordinates ξ, η. Then the transformation back to the x,y-coordinates in the flow planes and the solution of boundary problems become complicated. In the present note authors give an approximate solution of the gas dynamic equations for Mach number range from $1.15 \leq M \leq 2.35$ directly in the form $x = x(\xi, \eta)$, $y = y(\xi, \eta)$, which makes considerably easier the solution of the fundamental boundary problems. This Mach number interval corresponds to the first interval in the approximations of S. A. Khristianovich [*Prikl. Mat. Mekh.* **11,** 2, 1947]. H. Bilharz, Germany

3460. Ludford, G. S. S., and Martin, M. H., One-dimensional anisentropic flows, *Comm. pure appl. Math.* **7,** 1, 45–63, Feb. 1954.

This is a mathematical study of one-dimensional unsteady adiabatic flows of a gas in which the specific entropy varies from one fluid particle to another (anisentropic flow). Viscosity, heat conduction, and radiation are neglected. The analysis is based on the Monge-Ampere partial differential equation, and various types of anisentropic, as well as isentropic, flows are thereby discussed. A concrete example of an anisentropic flow is given. A physical example of an anisentropic flow is stated to be the adiabatic flow behind a decaying shock such as arises when an expansion wave overtakes a shock. M. Morduchow, USA

3461. Pai, S. I., On turbulent jet mixing of two gases at constant temperature, *J. appl. Mech.* **22,** 1, 41–47, Mar. 1955.

Paper continues author's researches on jet mixing when the fluid into which the jet enters is allowed to be different from the fluid of the jet itself. Laminar mixing was discussed earlier [AMR **6,** Rev. 2585]. Here the theory is extended to isothermal turbulent mixing (1) of two uniform streams, (2) of a two-dimensional jet from small slit, and (3) of an axially symmetrical jet from a small opening. The assumption is made that the turbulent exchange coefficient for density is equal to that for velocity and there is some discussion of the effect of this assumption.

D. C. Pack, Scotland

3462. Wyatt, DeM. D., Analysis of errors introduced by several methods of weighting nonuniform duct flows, *NACA TN* 3400, 40 pp., Mar. 1955.

Various weighting methods are applied to typical nonuniform duct flow profiles to determine average flow properties. The analysis covers a range of subsonic duct Mach numbers, but is confined to flows having uniform static pressure and total temperature.

An averaging method is developed which yields uniform properties that reproduce the mass and momentum of the nonuniform flow. In contrast, it is shown that the use of conventional weighting methods may result in large errors in these properties. These errors are shown to have varying significance depending on the applications to which the data are applied.

From author's summary by A. Kahane, USA

3463. Summerfield, M., Foster, C. R., and Swan, W. C., Flow separation in overexpanded supersonic exhaust nozzles, *Jet Propulsion* **24,** 5, 319–321, Sept.-Oct. 1954.

Paper discusses experiments with a 750-pound thrust rocket motor in which pressure distributions along the walls of conical nozzles (half angles of 10°, 15°, and 20°) were made for pressure ratios in the range in which jet detachment occurred. Analysis of the results on the basis of one-dimensional theory indicated that the effective angle between the wall and the separated jet boundary was almost independent of nozzle divergence angle, and that it was relatively unaffected by changes in pressure ratio, gas temperature, adiabatic expansion exponent, and nozzle length. J. V. Becker, USA

3464. **Ludloff, H. F., and Friedman, M. B., Aerodynamics of blasts—Diffraction of blast around finite corners,** *J. aero. Sci.* 22, 1, 27–34, Jan. 1955.

The diffraction of a strong shock at a finite concave corner is treated by two methods. In the first, conical coordinates reduce the appropriate equations to elliptic form with boundary conditions given on the wall and on the reflected and Mach shocks (location not known a priori). The singularities at the wall corner and at the point where the slipstream meets the wall are analyzed and the solution suitably expanded in these regions. A numerical solution of this type was found to agree very well with a shock-tube interferogram.

In a second method authors propose a direct integration by a finite difference method of the time-dependent equations (hyperbolic), starting with known initial conditions to avoid the necessity of meeting boundary conditions at an unknown location. According to authors, the finite difference equations automatically provide for shock discontinuities since second-order terms perform role of viscosity in equation of motion. Preliminary calculations by hand show roughly the formation of the Mach and reflected shocks. It is suggested that use of the conical character of the flow in the second method may increase the speed of convergence. J. A. Fay, USA

3465. **Moore, F. K., Unsteady oblique interaction of a shock wave with a plane disturbance,** *NACA Rep.* 1165, 21 pp., 1954.

Supersedes article reviewed in AMR **6**, Rev. 2836.

Wave Motion in Fluids

(See Revs. 3265, 3408)

Turbulence, Boundary Layer, etc.

(See also Revs. 3316, 3445, 3446, 3461, 3508, 3538, 3552)

3466. **Loos, H. G., A simple laminar boundary layer with secondary flow,** *J. aero. Sci.* **22**, 1, 35–40, Jan. 1955.

Exact solution of laminar boundary-layer equations is derived for flow over flat plate when free streamlines have parabolic shapes in planes parallel to plate. If x, y, z are, respectively, normal to leading edge, normal to plate, and along leading edge, then corresponding free-stream velocity components are U = constant, $V = 0$, $W = a + bx$.

No cross flow occurs in boundary layer when $b = 0$, i.e., when parallel stream approaches swept plate and there is no pressure gradient.

Dimensionless profile of the secondary-flow "cross" velocity (normal to local free-stream direction) is everywhere the same. For special case where $a = 0$ (streamlines are normal to leading edge), magnitude of cross velocity varies with distance along streamline in proportion to 2θ, where θ is flow direction relative to x.

Dimensionless profile of "tangential" velocity (parallel to local free-stream direction) changes with position along streamline because of pressure gradients. For adverse pressure gradient along streamline, "tangential" profile has reversed velocities near wall typical of ordinary "separation"; however, real separation does not occur because secondary flow transports high-energy fluid to critical region.

Because of the free-stream variation in total pressure, the secondary flow may allow the total pressure within the boundary layer to exceed that of the free stream at the same location.

Paper sheds some light on certain problems of secondary flow. It confirms principal results found by earlier workers.

A. H. Shapiro, USA

3467. **Graham, Martha E., Calculation of laminar boundary layer flow on rotating blades,** Cornell Univ. Grad. School aero. Engng., Ithaca, N. Y., 88 pp., Sept. 1954.

For an incompressible fluid, momentum methods are used to describe three-dimensional boundary layers of the "nearly two-dimensional" type—such boundary layers as occur on portions of helicopter or propeller blades far from the axis of rotation. Previous theoretical studies related to this problem are reviewed thoroughly. Velocity profiles describing chordwise flow are taken to be a one-parameter family of curves given by the Pohlhausen quartic. Spanwise velocity is divided then into two components—one associated with spanwise pressure gradient and centrifugal force, and one associated with Coriolis force. The momentum method is applied to each component, the velocity profiles for each component being defined by a one-parameter family of curves. Yawed-cylinder flow must be added to the two afore-mentioned components in order to adjust the position of the axis of rotation, since spanwise flow was computed assuming that no spanwise flow occurred at the stagnation point. Solutions are obtained by step-by-step numerical procedures. A solution obtained by Fogarty [AMR **4**, Rev. 4215] for a special cross section compares favorably with the solution obtained by the author for the same problem. Boundary-layer flows are computed for two new cases—a blade with a circular-cylinder cross section, and a blade with a laminar-flow-airfoil cross section. E. L. Knuth, USA

3468. **Eichelbrenner, E. A., Observations on a criteria of laminar flow in the three-dimensional boundary layer** (in French), *Rech. aéro.* no. 40, 3–5, 1954.

Extending the Pohlhausen method to the case of laminar three-dimensional boundary layer, authors clarify the geometrical relation between the limiting streamlines and the separation line when Sears separation criterion $(\partial\vartheta^*/\partial n)_{\text{wall}} = 0$ is applied, ϑ^* being the projection of the boundary-layer velocity vector on a given direction. W. Van Le, USA

3469. **Ross, D., A new approach to turbulent boundary layer problems,** *Proc. Amer. Soc. civ. Engrs.* **81**, Separ. no. 604, 24 pp., Jan. 1955.

Author considers, as a physical concept, a two-dimensional, turbulent boundary layer to be divided into three regions, viz., (1) an inner region wherein the local wall conditions predominate and the velocity profile $u/u_* = 5.6 + 5.6 \log yu_*/\nu$, where $u_* \equiv (\tau_w/\rho)^{1/2}$, is valid for $y/\delta < 0.1$ and $yu_*/\nu > 20$; (2) in outer region where $(1 - u/u_1) = D(1 - y/\delta)^{3/2}$ is valid for approximately the outer 75% of the boundary layer with D being an empirical constant depending upon the spatial history of the flow; and (3) a blending region between inner and outer parts which is partially dependent on local conditions and partially on spatial history. The inner region is related to the outer one through a relationship between D and the shear stress at the wall. This relationship is based upon a number of simplifying assumptions and correlations with existing experimental data, and it is found that D varies from about 0.3 for a flat plate to approximately 1.3 near separation. The profile in the blending region consists merely of a "smooth" curve connecting the profiles from the inner and outer regions. A. Ritter, USA

3470. **Ashkenas, H., and Riddell, F. R., Investigation of the turbulent boundary layer on a yawed flat plate,** *NACA TN* 3383, 57 pp., Apr. 1955.

Authors report on comprehensive low-speed tunnel tests on the turbulent boundary-layer development on the flat plate in yaw. The plate was yawed 0°, 30°, and 45°, and boundary-layer profiles, boundary-layer growth, and virtual origin of the boundary

layer when the turbulence is promoted by sandpaper near the leading edge were measured for a fixed Reynolds number of 250,000 per ft. Precautions were taken to ascertain that the flow over the plate was two-dimensional, which was found to be particularly important in order to obtain reliable results.

Contrary to the results of Young and Booth, it was found that the boundary-layer development does not follow the so-called "independence principle" of laminar flow. Theoretical considerations show also that the validity of this principle in turbulent flow would be difficult to explain. It is felt, therefore, that Young and Booth's results may be affected by deviations from two-dimensional flow.

The boundary-layer growth of the yawed plate in the streamwise direction was slightly greater than of the unyawed plate. Authors find an empirical growth law. They emphasize, however, that this may only apply to the specific test setup used.

In spite of the limited result, the paper contains a considerable amount of valuable information on the theoretical and experimental approach to the clarification of turbulent boundary-layer flow on yawed bodies. H. J. Ramm, USA

3471. Wallis, R. A., The turbulent boundary layer on the articulated nose of a thin wing provided with air jets, *Aero. Res. Lab. Melbourne, Austral.* A.R.L./A.141, 19 pp., 1 table, 22 figs., Oct. 1954.

Boundary-layer measurements were made at the leading edge of a thin airfoil section in steep adverse pressure gradients. The boundary layer was made turbulent by blowing air through small holes along the airfoil leading edge. Various auxiliary equations which have been proposed for calculating the chordwise growth of the turbulent-boundary-layer shape parameter H and for predicting trailing-edge separation are compared with the measurements. The calculated increments in H are several times as great as those measured. G. E. Nitzberg, USA

3472. Clarke, J. H., Menkes, H. R., and Libby, P. A., A provisional analysis of turbulent boundary layers with injection, *J. aero. Sci.* **22,** 4, 255–260, Apr. 1955.

Paper extends Prandtl's analysis of incompressible turbulent boundary layer to include effect of uniform transverse fluid injection. Nondimensional parameters are determined. Velocity profile is that for plane wall and reduces to universal log law when mass transfer is zero. Von Kármán integral approach yields variation of average skin-friction coefficient with injection ratio and Reynolds number based on streamwise coordinate. Comparison with available experimental results shows satisfactory agreement.

From authors' summary by S. Ostrach, USA

3473. Frenkiel, F. N., Effects of wire length in turbulence investigations with a hot-wire anemometer, *Aero. Quart.* **5,** part 1, 1–24, May 1954.

A very useful collection of formulas for the possible errors of the hot-wire technique with regard to the finite length l of the wire. Dependency of the measured longitudinal energy on l/L_y (L_y = transverse scale of turbulence), measurements of correlation coefficients with two hot wires, and scale and microscale of turbulence are discussed. K. Wieghardt, Germany

3474. Dannenberg, R. E., and Weiberg, J. A., Exploratory investigation of an airfoil with area suction applied to a porous, round trailing edge fitted with a lift-control vane, *NACA TN* 3498, 55 pp., Apr. 1955.

A method of obtaining lift independently of the incidence of an airfoil by means of a vane moved about a porous, round trailing edge through which suction was applied was suggested by Thwaites in 1947. In order to assess the effectiveness of this method, authors have carried out wind-tunnel tests of a modified NACA 65_1-012 airfoil, at a Mach number of 0.14 and a Reynolds number of 4.2×10^6. Lift coefficients of 1.9 were obtained with a 5% chord vane and 2.5 with a 20% chord vane, at zero angle of attack. With suction off, the respective lift coefficients were 0.7 and 1.5. For efficient lift control, the porous region should extend from the point of minimum pressure to the trailing edge and the suction quantity should be such as to just eliminate the trailing-edge separation. J. Lukasiewicz, Canada

Aerodynamics of Flight; Wind Forces

(See also Revs. 3265, 3299, 3300, 3317, 3406, 3407, 3453, 3455, 3456, 3464, 3470, 3471, 3474, 3485, 3488, 3493, 3560, 3561)

3475. Brown, C. E., and Michael, W. H., Jr., On slender delta wings with leading-edge separation, *NACA TN* 3430, 27 pp., Apr. 1955.

The slender-body approximation of linearized compressible flow is applied to the problem of a delta wing in which flow separation occurs at the leading edges. The vortex sheets found in the real flow are approximated by concentrated vortexes with feeding lattices, and a plausible adaptation of Kelvin's theorem is applied to simulate the force-free nature of the vortex sheet.

The computations show that leading-edge separation produces an increase in lift over that given by the Jones slender-wing theory and that the lift does not vary linearly with angle of attack. Computed pressure distributions and span loadings are presented and the theoretical lift results are compared with the results of simple force tests made at a Mach number of 1.9.

From authors' summary by L. G. Napolitano, USA

3476. Heaslet, M. A., and Fuller, F. B., Axially symmetric shapes with minimum wave drag, *NACA TN* 3389, 46 pp., Feb. 1955.

The external wave drag of bodies of revolution moving at supersonic speeds can be expressed either in terms of the geometry of the body or in terms of the body-simulating axial source distribution. For purposes of deriving optimum bodies under various given conditions, it is found that the second of the methods mentioned is the more tractable. By use of a quasi-cylindrical theory, that is, the boundary conditions are applied on the surface of a cylinder rather than on the body itself, the variational problems of the optimum bodies having prescribed volume or caliber are solved. The streamwise variations of cross-sectional area and drags of the bodies are exhibited, and some numerical results are given. The solutions are found to depend upon a single parameter involving Mach number and the radius-length ratio of the given cylinder. Variation of this parameter from zero to infinity gives the spectrum of optimum bodies with the given condition from the slender-body result to the two-dimensional. The numerical results show that, for increasing values of the parameter, the optimum shapes quickly approach the two-dimensional.

A reciprocity relation for axial flow is derived, and it is used in formulating the variational problems in terms of the drag formula involving geometry. Formulation of the minimum problems in terms of combined flow fields is found to lead to extremely simple relations that are satisfied by the flow fields induced by optimum bodies. The combined flow concepts are also useful, for example, in checking results found by other means.

From authors' summary by H. H. Hilton, USA

3477. Woods, L. C., The lift and moment acting on a thick aerofoil in unsteady motion, *Phil. Trans. roy. Soc. Lond.* (*A*) **247,** 925, 131–162, Nov. 1954.

Mathematical theory of thick airfoil in unsteady motion is developed, based on analytical character of function $f = \ln[U(dz/dw)] = \ln(Ue^{i\theta}/q)$; U undisturbed velocity, q velocity vector in polar coordinates, $w = \phi + i\psi$ complex stream function; using ϕ_0 and ψ_0 (referring to mean steady no-lift flow) as independent variables. First, integral representation expressing f in values of θ at airfoil contour and jump of U/q across wake is derived. Next, conditions in wake are deduced from Kelvin circulation theorem and Helmholtz persistence law, assuming wake situated along trailing edge streamline of mean steady flow, its vorticity being carried off by corresponding steady but spatially variable velocity (approaching U far downstream). The involved presentation of the mean steady no-lift flow incorporates parameter open to empirical correction for viscosity; another such parameter is made available by using substitute for Kutta condition allowing rear stagnation point "viscous slip" across trailing edge in proportion to local normal velocity.

Lift and moment are finally obtained from Blasius theorem. Results are specialized to case of harmonic oscillation of rigid airfoil. Checks with experiment show that theory explains part of differences between measured aerodynamic coefficients and conventional thin airfoil theory.

Final formulas are complicated, but applications might not be too difficult. Reviewer considers paper remarkable mathematical achievement. It is, however, not easily surveyable and is difficult to read. Certain features of analysis are very difficult to assess.

J. H. Greidanus, Holland

3478. Dugan, D. W., and Hikido, K., Theoretical investigation of the effects upon lift of a gap between wing and body of a slender wing-body combination, *NACA TN* 3224, 41 pp., Aug. 1954.

Cases (a) wing and body same angle of attack, and (b) wing only deflected relative to free stream, are solved by application of slender-body theory; combined angle of attack and wing deflection case is determinable by superposition. Theory is restricted to vanishingly thin wings at very small angles of attack and wing deflection.

Large losses of lift even for minute gap widths are predicted; here neglect of viscosity and compressibility produces unrealistic results. Range of gap widths and angles of attack for which present inviscid theory is reasonably valid can only be determined experimentally. At higher angles of attack and/or large gap width vortex, separation from edges would probably play an important role in determining gap effect. Reviewer suggests that these cases could be treated by adoption of a simplified mathematical model of flow; e.g., as given by H. K. Cheng [*J. aero. Sci.* **21,** 3].

Same results as present paper were obtained by Mirels [AMR **7,** Rev. 1899], but solution for case (b) was not obtained in closed form.

J. S. Isenberg, USA

3479. Pocock, P., and Laundry, W. E., Some aerodynamic characteristics of delta wings at low speeds, *Proc. 2nd Canadian Symposium on Aerodynamics, Inst. of Aerophysics, Univ. of Toronto,* Feb. 1954, 39–68.

Paper describes results of experimental research on four delta wings with similar planform ($A = 2$) but different profile shape. Work is to be extended to include six profile forms. It is mainly the leading edge shape which has been varied. The flow has been visualized with the chalk-kerosene method, with surface wool tufts and tuft screens. The influence of the leading edge shape on the formation and position of the leading edge vortex has been studied. It is also shown that the leading edge shape has a large influence on the span efficiency factor and on the nonlinearity of the lift curves.

The work is a very nice contribution to the not-to-well understood problem of the flow pattern of delta wings at incidence. For further information reader could also consult recent paper by Örnberg [AMR **8,** Rev. 183].

T. R. Gullstrand, Sweden

3480. Redshaw, S. C., The determination of the pressure distribution over an aerofoil surface by means of an electrical potential analyser, *Aero. Res. Counc. Rep. Mem.* no. 2915, 40 pp., 1954.

This paper is an enlarged reprint of a prior paper. In addition, it contains measurements on a circular lamina and investigations to determine the effect of boundary restraints.

K. Pohlhausen, USA

3481. Collins, W. D., A note on Stokes' stream-function for the slow steady motion of viscous fluid before plane and spherical boundaries, *Mathematika* **1,** 125–130, 1954.

In the case of simple axisymmetrical Stokes flows, it is shown that the stream function for the viscous flow, bounded by either a sphere, a plane, or a combination of both, can be expressed in terms of a stream function for an unbounded irrotational motion, such as a uniform flow, a source, a doublet, and so on.

Y. H. Kuo, USA

3482. Schlichting, H., Calculation of the frictionless incompressible flow for a given plane airfoil cascade (in German), *VDI-Forschungsheft* (*B*) **21,** 447, 47 pp., 1955.

In a previous paper [AMR **8,** Rev. 185], N. Scholz presented a solution of the incompressible inverse cascade problem by means of a simplified source and vortex distribution method. In the present paper, essentially the same analytical procedure is applied to the solution of the direct problem. Method is first outlined for the single airfoil case, using Glauert series expansions. It is then extended to the lattice case, leading to a more complicated form of the basic system of two coupled integral equations. However, the just solved case of the single airfoil enables computing as second step the velocities induced on it by the remaining lattice part only, thus simplifying again by eliminating the integral singularities. The whole procedure finally results in the solution of two systems, each of six linear equations, the coefficients of which may be obtained from a series of tables computed once for all. Furthermore, the method allows for varying any of the geometric parameters independently of the others, thus providing means for systematically investigating their influence on the aerodynamic ones.

Numerical applications to a number of cascade configurations show good agreement with experimental results and theoretical solutions obtained by means of exact methods.

Paper is very clearly written. In spite of its limitation to slightly cambered airfoil cascades, it represents, in reviewer's opinion, a remarkable contribution to the incompressible-lattice theory.

P. Schwaar, France

3483. Charters, A. C., The linearized equations of motion underlying the dynamic stability of aircraft, spinning projectiles, and symmetrical missiles, *NACA TN* 3350, 102 pp., Jan. 1955.

Starting from the Newtonian relations that the total force vector is equal to the rate of change of the momentum vector, and that the total moment vector is equal to the rate of change of moment of momentum vector, author develops the linearized equations of motion of aircraft having mirror symmetry and spinning projectiles or missiles with rotational and mirror symmetry.

This paper attempts to develop, using standard aeronautical nomenclature, a unified theory of motion for both aerodynamic and ballistic work.

In general the development of the equations follows the classical methods for dealing with perturbed flight about a steady condition. The dynamical turns are introduced with respect to a moving triad system, and aerodynamic forces and moments are expressed in a formal series expansion involving the standard stability derivatives. For the aircraft case, the resulting equations include some terms which are frequently neglected in aircraft work, but often retained in the analyses of high-speed missiles. The equations derived for this case must be considered as somewhat restricted, since terms involving control deflections and rates of change thereof are not included, although their inclusion would present no trouble.

For the case of projectiles and missiles possessing mirror and 90° rotational symmetry, author uses an axis system similar to that employed by Nicolaides [*BRL Rep.* 858, June 1953]. This "pseudo-stability" axis is fixed in the missile in pitch and yaw, and fixed in space in roll. Under the assumptions common to small-perturbation theory (any change in velocity or roll rate is a small perturbation on a steady value, pitch and yaw angles and rates of change of same are small, as well as pitch and yaw angles of attack), the author sets up the differential equations of motion. Magnus terms are introduced in the series expansion for aerodynamic force and moment. A complex variable approach similar to that of *BRL Rep.* 858 is employed, and a solution is obtained similar to Nicolaide's, although now covering the case of a small perturbation in roll rate but not allowing for any configurational asymmetries. The application of these equations to free-flight range tests is discussed.

Reviewer feels that this paper, while presenting no substantially new results, achieves its worth-while purpose in providing a common theory for aircraft and ballistic work. The author treats in a thorough and competent manner many of the troublesome details frequently assumed but not proved (e.g., the consequences of 90° rotational symmetry). Further, he makes well the point of carefully considering the order of magnitude of terms involved in the equations before neglecting any, specifically in relation to linearizing the equations of motion.

A worth-while addition to this paper would be some discussion of the methods of dealing with the linearized differential equations of motion under the commonly encountered flight conditions of rather large changes in roll rate and/or appreciably varying flight velocity. To the reviewer's knowledge, no explicit analytical method exists for this case, and automatic computing devices are usually employed. Considering the widespread use of analog and digital computers in conjunction with free-flight testing techniques, it is rather surprising to find no consideration made of this method in discussing reduction of aerodynamic range data. G. V. Bull, Canada

Aeroelasticity (Flutter, Divergence, etc.)

(See also Revs. 3313, 3317)

3484. Woolston, D. S., and Runyan, H. L., Some considerations on the air forces on a wing oscillating between two walls for subsonic compressible flow, *J. aero. Sci.* **22,** 1, 41–50, Jan. 1955.

The integral equations for the compressible case [*NACA TN* 2552] are briefly reviewed and a method of solution is given. The effects of compressibility are significant in the measurement of oscillating air forces or wing flutter characteristics in wind tunnels, and in the flutter of airfoils in cascade. One of the approximations employed in the solution does not hold at or close to Mach one. The possibility of an acoustic resonance phenomenon under certain critical conditions is pointed out for the case of three-dimensional tunnels of rectangular and circular cross section.

Three specific aspects of the wall effect problem have been worked out; these are: (1) Lift on an oscillating wing for various (subsonic) Mach numbers at constant wall distance; (2) effects of varying the distance between tunnel walls, and (3) flutter of an airfoil between walls or in cascade compared to flutter in free flight. H. P. Liepman, USA

3485. Hanocq, Ch., Fluid mechanics applied to the study of shells and wings (in French), Liège, Imprimerie H. Vaillant-Carmanne, S. A., 94 pp., 1954.

In this unorthodox treatment, author calculates aerodynamic forces by replacing flow past body by imaginary flow consisting of flux of finite width in which streamlines are approximated by concentric circular arcs. The force developed on body is demonstrated to depend only on the difference in the orientation of the main flow velocity, and the velocity at the point of inflection of the imgainary streamlines, or, in the case of airfoils, in the deviation of the flux past a curved plate which replaces the airfoil. The work done in moving a body through a fluid at rest is accounted for by the dissipation of the component of velocity perpendicular to the direction of movement at the forward point of inflection. From this, author states that the regime of laminar flow past a body observed in a wind tunnel cannot exist if the body moved in a fluid at rest.

The paper is divided into seven parts. In part I, the ratio of the width of the imaginary flux to the radius of curvature of the approaching streamline is established from experimental results, and forces on flat plates, circular cylinders, spheres, and airfoils are evaluated. Part II extends the concept to compressible flow and discusses critical Mach number and shock formation. An explanation of "sonic bang" is also included. In part III, results for friction coefficients for flow past rough and smooth bodies are collected, and in part IV the total forces on ships' hulls are calculated. The loss of the perpendicular velocity component at the forward inflection point accounts for the accompanying wave losses. Part V is devoted to the lift of airfoils and finite wings. Part VI gives a qualitative discussion of transonic flow, and suggests suitable wing and fuselage forms, and the final section, part VII, covers some possible criticisms of the paper and presents general conclusions, including an example in which the method is applied to turbomachinery.

Author concludes that the method used provides a simple hydraulic approach to calculation of aerodynamic forces.

R. N. Cox, England

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 3294, 3314, 3335, 3433, 3502, 3503, 3511, 3536, 3553, 3556, 3557, 3559)

3486. Draper, J. W., and Kuhn, R. E., Some effects of propeller operation and location on ability of a wing with plain flaps to deflect propeller slipstreams downward for vertical take-off, *NACA TN* **3360,** 28 pp., Jan. 1955.

An investigation has been conducted of the effects of propeller blade angle, mode of propeller rotation, propeller location, and ratio of wing chord to propeller diameter on the ability of a wing with plain flaps to deflect the propeller slipstream downward in order to achieve vertical take-off. The basic model consisted of a semispan wing with 30 per cent chord and 60 per cent chord plain flaps. Two large-diameter overlapping propellers driven by electric motors were used. From authors' summary

3487. Stepanoff, A. J., Turboblowers. Theory, design and application of centrifugal and axial flow compressors and fans, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1955, ix + 377 pp. $8.

This new book by Dr. Stepanoff fills a long-felt need in the fields of blower and compressor design. The work is admirably executed to achieve the author's purpose of unification of the fundamental hydrodynamic relationships which are applied to all turbomachines and to take the basis of design away from the indirect thermodynamic basis. The reader of Dr. Stepanoff's previous book, "Centrifugal and axial flow pumps," will find many familiar treatments and diagrams in the new volume; the new material is concerned with the compression and pumping of gases for about 60% of the work presented.

This book will be considered as a must for any designer of turbomachinery and field-handling equipment for gaseous flow. It is an excellent combination of essential theoretical arguments and empirical design information which allows the reader to obtain a good basis in fundamental considerations and, at the same time, to be able to design an actual unit using conservative empirical coefficients. Design information applying to the mean geometries and performances of blowers and compressors now in operation and presented in chart form forms an essential contribution.

In order to read the book, it is assumed that the reader has a sound knowledge of fluid mechanics, mechanics, and thermodynamics. Chaps. 1–6, inclusive, and 9 and 10 involve the presentation of fundamentals that apply equally well to all turbomachinery handling compressible or incompressible fluids. Following his introductory statement in chap. 7, which includes "Since the proof of the thermodynamic laws and doctrines is based on the appeal to reason, and because no two minds reason in the same manner, there is a considerable variation in presentation of the subject in various treatises on thermodynamics," author defines and describes the importance of "available energy function." It is anticipated that many thermodynamicists will take violent issue with the available energy discussions included by the author.

Following this uncommon treatment of thermodynamics, chap. 8 presents the characteristics of a real gas, including compressibility examples where the Mach number (associated with the velocity of sound) enters, as well as heating and cooling possibilities. Chaps. 11–15, inclusive, contain the material associated with turbomachinery handling a compressible fluid. This treatment is reasonably complete, and an engineer will be able to carry out a reasonable design of a new unit on the basis of the design charts, empirical design factors, descriptions, performance data, and applications as presented in the volume. Chap. 16 deals with the layout and design of a mixed-flow impeller blade with specified conditions and has much in common with the similar chapter in the earlier book.

In the publication of this volume, Dr. Stepanoff has made available important contributions from theory and experiment of great usefulness and importance to students and designers of turboblowers. R. G. Folsom, USA

3488. Schäffer, H., Investigations on three-dimensional flow through axial blade rows with cylindrical blading (in German), *Forsch. Geb. Ing.-Wes.* (*B*) **21,** 1, 2; 9–19, 41–49, 1955.

The pressure distribution over the blades, and the velocity components and pressure distribution behind a fixed three-dimensional annular cascade with various hub-to-tip radius ratios R_N* and with several numbers of blades have been measured and compared with the results of measurements on a two-dimensional cascade.

The flow and the pressure distribution at various distances from the hub of the annular cascade have been compared with those of two-dimensional cascades where the distance between the blades is the same as that of the annular cascade at the various distances from the hub. In this way it appears that the curves for the pressure distribution over the blade chord for both types of cascades resemble each other satisfactorily, apart from deviations in the neighborhood of the hub at the exit of the blade disk for R_N* = 0.4, 0.5; author used for R_N* the values of 0.4, 0.5, 0.65, and 0.8.

The curves giving circulation against the distance of the blades for the annular cascade and for various two-dimensional cascades show that the increase of the circulation for the former is less than that for the latter; in the case of the annular cascade the circulation decreases in the neighborhood of the outer wall due to boundary-layer effects; as to the increase of the velocity in axial direction in the neighborhood of the hub, the increase of circulation there is more than for the two-dimensional cascade.

The total pressure losses of the blade disk, including boundary losses due to secondary flows, can be deduced from those of the two-dimensional cascade; the same is the case for the discharge angle. Due to these results the discharge flow behind angular cascade can be calculated from the coefficients of the two-dimensional cascade, which is shown by an example.

From author's summary by E. M. de Jager, Holland

3489. Pearson, C. E., A study of surge in compressors and jet engines, *J. aero. Sci.* **22,** 1, 10–16, Jan. 1955.

Two of the most difficult problems in the gas-turbine field have always been: how to design compressors which do not surge easily or violently, and how to predict and prevent compressor surge when an engine is accelerated.

An experiment on a single-stage centrifugal compressor is quoted here to justify the common assumption that steady-flow compressor characteristics may be used to deduce transient performance. This question resolves itself into whether the time delay of the boundary layers in responding to changes of air-flow angles is short compared with the duration of the performance transient. A theoretical model of a jet engine is then set up as a set of six nonlinear differential equations, and the stability is discussed.

A number of rather general conclusions are reached; perhaps the most interesting is that any design change which increases the sharpness of the efficiency-flow curve will always make surge more likely. Reviewer's experience is that this statement is correct.

It is to be hoped that author's valuable observations on compressors [AMR **7,** Rev. 2204] will lead to a hypothesis of surging and final understanding of the mechanism. But the publication of studies of simplified models is of limited utility unless direct recommendations can be given to designers—and this article gives none. J. M. Stephenson, USA

3490. Moyer, W. B., Operating experience on General Electric gas turbines, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-160, 14 pp.

Paper summarizes the operating experience on 71 General Electric gas turbines while accumulating over 345,000 hr of operation. Operating problems and maintenance on gas turbines are discussed. First-stage nozzle-temperature shock cracks, compressor and turbine fouling, fuel-nozzle fouling, and combustion-liner replacement are being steadily removed from their former status as operating problems to that of acceptable maintenance. Operating experience on each application is discussed, so that an over-all picture is obtained as to the excellent record already attained by this new type of prime mover.

From author's summary

3491. Bright, P. N., Structural-design problems in gas-turbine engines, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-152, 26 pp.

3492. Hull, T. N., Jr., Gas-turbine bucket-operating experience and bucket and wheel design method, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-172, 16 pp.

3493. Anonymous, Report of the definitions panel on the definitions of the thrust of a jet engine and of the internal drag of a ducted body, *Aero. Res. Counc. Lond. curr. Pap.* 190, 28 pp. May 1954, published 1955.

The problems which occur in defining the thrust of a jet engine and the internal drag of a ducted body are considered, and formal definitions and names are given for the concepts considered to be of importance. From summary

3494. Baumann, G., Increasing the output of two-stroke engines by means of exhaust-gas turbochargers, *Brown Boveri Rev.* **41,** 8, 287–311, Aug. 1954.

A concise but thorough analysis of the application of turbosupercharging based on fundamental thermodynamic principles as well as operating experience. Included are structural and thermal engine problems associated with increased load, theoretical and practical improvements in output from the engine, scavenging schemes and arrangements, optimum engine design and operation for maximum benefit, and probable future trends. E. S. Starkman, USA

3495. Fitzgeorge, D., and Pope, J. A., An investigation of the factors contributing to the failure of Diesel-engine pistons and cylinder covers, *N. E. Cst. Instn. Engrs. Ship. Trans.* **71,** part 5, 163–236, Mar. 1955.

3496. Johannis, E., Air requirement for starting of Diesel engines (in German), *Motortech. Z.* **15,** 4, 99–104, Apr. 1954.

3497. Fulleman, J., and Kuivinen, T. O., Centrifugally scavenged two-cycle engines, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-254, 13 pp.

Centrifugal scavenging is a natural for the two-cycle engine. Air flows match engine need throughout the speed range, resulting in higher efficiency, lower fuel consumption, and greater load capacity. Mechanical design of the blower drive evolves from performance of a prototype unit. From authors' summary

3498. Gamse, S. M., and Goldscher, A. J., Technology of manufacture of large hydraulic turbines [Technologie der Herstellung von Grosswasserturbinen] (translated from Russian), Berlin, VEB Verlag Technik, 1954, 362 pp.

Book seems to be based mainly on the work of the LMZ Leningrad Works which are said to have built hydraulic turbines of the propeller (Kaplan) and Francis types up to 75,000 kw, and on lectures at the Leningrad Polytechnic. It contains chapters as follows: I. Brief description of large Francis and Kaplan turbines and their components; II. General description of manufacturing and assembly processes, workshop layout, machine tools and their limits of accuracy, permissible errors, and means for measuring large dimensions; III. Materials and semifinished products, including a brief paragraph on rubber and "lignofol" (wood) bearing linings; IV. Ways and means for improving manufacturing processes, description of some of the cutting tools and mechanization of manual operations; V. Analysis of manufacturing processes of Kaplan-type runners; VI. The same for Francis-type runners, including a brief note on transportation of such by rail; VII. Analysis of manufacturing processes for parts of regulating mechanism, such as gates, etc.; VIII. Ditto for shafts, bearings, and servomechanisms; IX. Steel plate welded volute casings, development of contours, forming, assembly, and welding; X. Balancing (static) of runners on single ball fixture, including analysis of features influencing precision of such balancing; XI. Standardization and improvements of design for ease of manufacture.

Authors concentrate almost exclusively on the machining of large components of Kaplan and Francis turbines, with particular attention to errors of machining and their cumulative effect on assemblies. A notable omission is the lack of a chapter on the technology of production of large castings, although the authors claim that world's largest one-piece Francis-type runner weighing 92 tons was produced in USSR. There are only a few references to works of Russian origin, and none to Western publications, except to Timoshenko's "theory of elasticity." Drawings and charts are of the high standard usually associated with German technical publications, but photograph reproductions are very poor.

Reviewer considers book to be suitable as a text for university students intending to specialize in heavy engineering. Practicing engineers in that field will find little new there, except possibly a reminder of the importance of standardization, which is given in the last chapter. J. J. Dziewonski, India

3499. Willm, G., and Campmas, P., Efficiency measurements for hydraulic turbines by the Poirson thermometric method (in French), *Houille blanche* **9,** 4, 5; 449–460, 590–607, July/Aug., Sept./Oct., 1954.

An extensive account of the thermometric method of measuring the efficiency of turbines is given. The method, which to the reviewer's knowledge has not been used extensively in recent times, consists basically in comparing the variation of total energy of the water (internal plus hydraulic) between entrance and exit of the turbine with the corresponding variation of hydraulic energy only.

Thermodynamic principles and reasoning are introduced for the evaluation of the variation of internal energy, and there results a formula which directly gives the efficiency of the turbine in terms of elevation, pressure, velocity, and temperature in two sections upstream and downstream of the turbine, and of the physical characteristics of the water. Possible causes of error in the application are analyzed.

The practical problems to be solved in the actual use of the method are also examined. The interesting instrumentation developed in this connection is accurately described.

Finally, some results obtained with the thermometric method are given and compared with those yielded by conventional procedures. The agreement is quite good and confirms the reliability of the method. P. L. Romita, Italy

3500. Rodert, L. A., and Garrett, F. B., Ingestion of foreign objects into turbine engines by vortices, *NACA TN* 3330, 23 pp., Feb. 1955.

The ingestion of foreign objects by vortexes formed between engine inlet and ground surface was investigated with a 5000-pound-thrust axial-flow jet engine. Pebbles, typical of objects that damage jet engines, were projected into the air by the vortexes and were drawn into the engine by the high-velocity inlet-air stream. Vortex formation depended on engine speed, engine height, and surface wind. Pebbles lodged in surface cracks were more readily picked up than those exposed on a smooth surface. From authors' summary

3501. Kramer, J. J., and Stanitz, J. D., A note on secondary flow in rotating radial channels, *NACA Rep.* 1179, 12 pp., 1954.
Supersedes article reviewed in AMR **8**, Rev. 1485.

Flow and Flight Test Techniques

(See also Revs. 3277, 3299, 3343, 3345, 3470, 3473, 3486, 3499 3523)

3502. Fister, W., Pressure distribution measurements on rotating turbine blades (in German), *VDI-Forschungsheft (B)* 21, 448, 32 pp., Aug. 1955.

A test arrangement for measuring the pressure distribution over the surface of a rotating turbine blade is described. The turbine is driven with cold air up to speeds of 10,000 rpm. The results are compared with measurement made on a two-dimensional stationary cascade. The turbine torque obtained directly with a fluid friction dynamometer is in good agreement with the torque which follows from the pressure distribution.

A. Betz, Germany

3503. Diehl, E. J., and Visser, H., The measuring of quickly changing pressures (in Dutch), *Ingenieur* **66**, 43, 0.71–0.77, Oct. 1954.

Report of results with pressure-measuring equipment developed by the Laboratory for Internal Combustion Engines of the Technological University of Delft. Design data of the capacity-type pickups are given.

Special attention is drawn to the fact that the measuring capacity is not connected to a bridge, but to an oscillator circuit with rectifiers; in this way it is possible to get a great amplification factor and, furthermore, to work with long cables (120 ft).

From authors' summary

3504. Ridland, D. M., The M.A.E.E. recording accelerometer, *Aero. Res. Counc. Lond. curr. Pap.* 177, 15 pp., Sept. 1952, published 1954.

The M.A.E.E. recording accelerometer is basically the accelerometer unit of a desynn accelerometer, adapted to make a continuous and immediate presentation of accurate, calibrated accelerations on a half-second time base.

The recording medium is metalized paper, having a speed of ½ in. per sec, and the instrument can be operated continuously for 20 min on one loading. It can record with full-scale deflections from 1 to 10 gg when the natural frequencies will be about 7 and 22 cps, respectively.

The instrument is simple; it has been proved reliable and accurate; and it is most convenient in use.

From author's summary

3505. Wilson, L. N., An experimental investigation of Reynolds number effects on supersonic static probes, *Univ. Toronto Inst. Aerophys. TN* 3, 24 pp., Sept. 1954.

Investigations have been carried out at Mach numbers of 4.13, 4.67, and 6.39 on a family of static probes in the 5 in. × 5 in. hypersonic wind tunnel at the Institute of Aerophysics. The variables investigated are the probe outside diameter and the orifice diameter. In the range of Reynolds numbers tested, there is no noticeable effect of these variables on static pressure readings.

Probe size appears to be an important factor only when there is a disturbance in the flow which interacts with the probe boundary layer and gives an incorrect reading.

The various Mach number calculations based on total head and static pressure readings are in good agreement below the critical Mach number for air condensation. Calculations based on the measured shock angle over a wedge showed the Mach number measured by this means to be unreliable.

From author's summary

3506. Dingeldein, R. C., Wind-tunnel studies of the performance of multirotor configurations, *NACA TN* 3236, 10 pp., Aug. 1954.

The power requirements measured in static thrust and in level forward flight are presented for a coaxial and a tandem helicopter rotor configuration. The experimental measurements are compared with the results of calculations based on existing NACA single-rotor theory. From author's summary

3507. Cope, W. F., Shadowgraphs of model projectiles fired at high Mach numbers and near $M = 1$ in the N.P.L. ballistic range, *Aero. Res. Counc. Lond. curr. Pap.* 189, 49 pp., July 1954.

Shadowgraphs of 20-mm projectiles fired in the N.P.L. ballistic range at Mach numbers (mainly) above 3 are shown, and the important features discussed.

Shadowgraphs of three rounds whose Mach numbers passed through $M = 1$ in their passage down the range are also shown. In all three cases the drag, and in one all the aerodynamic force coefficients, were determined. The effect of the retardation is discussed and it is concluded that the effect is probably small enough to be negligible, except perhaps on the drag.

These rounds were stable: the unstable region for projectile is at a lower Mach number (about 3/4). To illustrate this, the analysis of some earlier rounds is included.

From author's summary

3508. Trimpi, R. L., and Cohen, N. B., A theory for predicting the flow of real gases in shock tubes with experimental verification, *NACA TN* 3375, 69 pp., Mar. 1955.

Paper describes a study of the boundary layer in a shock tube and its effect on the flow of a real gas. Both skin friction and heat transfer are taken into account. The characteristic differential equations for a quasi-one-dimensional nonstationary flow in a tube are linearized and the evaluation of resulting integrals is made on an assumption relevant to conditions under which the unsteady and steady skin frictions may be regarded as equivalent.

The theory predicts that shock attenuation increases with distance and that static pressure, velocity, density, and Mach number at a fixed position in the state behind the shock wave increase with time, whereas the sound speed decreases. These effects have been verified experimentally. G. N. Patterson, Canada

3509. McIvor, J. W., Full-scale measurements of impact loads on a large flying boat. Part I. Description of apparatus and instrument installation, *Aero. Res. Counc. Lond. curr. Pap.* 182, 23 pp., Mar. 1950, published 1954.

The variations with time of the total force and the distribution of water pressures on the hull bottom of a flying boat are related to the horizontal velocity, vertical velocity, and keel attitude relative to the water during the impact. Methods are described for obtaining, in a form suitable for easy analysis of results, records of these variables, in order to verify impact theories.

The equipment used included transducers for the conversion of physical quantities to electrical signals, multi-channel electronic amplifiers and mirror galvanometer recorders. A shore-based cine camera, synchronized with the internal recorders, provided information on forward speed and rate of descent.

From author's summary

Thermodynamics

(See also Revs. 3265, 3277, 3288, 3416, 3448, 3449, 3463, 3487, 3489, 3490, 3493, 3497, 3502, 3530, 3536, 3540, 3541, 3546, 3558)

3510. Rossini, F. D., editor, Thermodynamics and physics of matter (High Speed Aerodynamics and Jet Propulsion, Vol. I), Princeton, N. J., Princeton University Press, 1955, xviii + 812 pp. $15.

This volume brings together the basic principles of the thermodynamics and physics of matter, presented from the standpoint of their applicability to a better understanding of high-speed aerodynamics and jet propulsion. Section A by F. D. Rossini covers the fundamentals of thermodynamics. In section B, K. F. Herzfeld and V. Griffing discuss quantum mechanics, molecular structure, bond energies, and activation energies; J. O. Hirschfelder, C. F. Curtiss, R. B. Bird, and Ellen Spotz present statistical mechanics and the kinetic theory of gases. Section C, by J. A. Beattie, gives a full treatment of thermodynamic properties of real gases and their mixtures. In section D, Hirschfelder, Curtiss, Bird, and Spotz discuss the transport properties of gases and gaseous mixtures. In section E, O. K. Rice covers critical phenomena, including association and condensation. Section F, by J. M. Richardson and S. R. Brinkley, presents the theories of liquids and liquid solutions. In section G, P. P. Ewald discusses solids and solid solutions, covering crystals, conductors, insulators, energy bands, and cooperative phenomena. Section H, by Herzfeld, covers relaxation phenomena in gases, including theory and experiment. In section I, I. Estermann presents a discussion of gases at low densities, including molecular beams. In section J, Curtiss discusses the thermodynamics of irreversible processes, including flow processes, viscosity, thermal conductivity, and diffusion.

Much of the material presented is a number of years old and represents condensations in many cases of discussions presented more fully elsewhere. As a general reference for the engineer who wishes to explore the theoretical foundations of thermodynamics, this will provide sufficient information and references to other sources to accommodate most current needs.

N. A. Hall, USA

3511. Leontovich, M. A., Introduction to thermodynamics [Vvedeniye v termodinamiku], 2nd ed., Moscow-Leningrad, Gos. Izdat. Tekh.-Teor. Lit., 1952, 199 pp., 15 figs.

This is a revised edition of the fine textbook for the Russian Universities, based on author's lectures to the students of physics and covering the wide field of physical questions connected with thermodynamics and their applications. The subject is presented from the phenomenologic viewpoint; the atomistic regard is outside the scope of the book. Nevertheless, in planning the work, author has obviously tried to prepare the reader for the study of statistical physics.

Material is grouped into three chapters containing 48 subsections. The first chapter (43 pp.), entitled "Fundamental concepts and theorems of thermodynamics," introduces the notion of a physical system and its thermodynamic state, deals with adiabatic processes, and explains the first law of thermodynamics with its use (reversible processes, enthalpy, steady flow of liquids and gases, etc.). At the end comes the second law of thermodynamics.

Following main part, "Thermodynamics of reversible processes and of equilibrium states" (65 pp.), deals in the first place with the free energy of a system, explains the role of integrating factors of complicated differential expressions, and deduces the basic theorem of reversible thermodynamics. Then comes the notion of entropy, the Carnot equation of reversible processes, and introduction of the thermodynamic Kelvin scale. Carnot cycle and problems on refrigeration (Joule-Thomson effect, magnetic methods) are also included. Thermodynamics of radiation develops the Kirchhoff and Stefan-Boltzmann laws, but reviewer has not found the thermodynamic proof of the radiation pressure.

Third chapter, "Equilibrium conditions. Nonequilibrium states and their use," has 84 pages. It discusses the changes in entropy of irreversible adiabatic processes and the role both of the entropy and free energy in establishing the equilibrium conditions of a system. Special attention is given to the theory of phases and to related questions. Reviewer expressly notes the Clapeyron-Clausius equation, equilibrium problem of three phases, detailed discussion of critical point and theory of condensation. Then comes discussion of phase changes of the second kind, the notion of Curie point, Gibbs formula, free energy in a mixture of ideal gases, and problems on equilibria in mixtures of such gases.

Book abounds in original ideas. Reviewer calls attention in the first place to the simplifying role of integrating factors, e.g., at deducing exactly the fundamental concepts of the thermodynamic Kelvin temperature and of entropy. Also theory of critical points as well as that of condensation contains very probably several new viewpoints. In the third chapter, author proposes an original way of generalizing thermodynamic functions to nonequilibrium states.

Apart from some philosophical objections in the Russian critique, the volume is, in reviewer's mind, one of the very successful works of this kind. It is warmly recommended to physicists and engineers. V. Vodička, Czechoslovakia

3512. Schmidt, A. F., and Spurlock, B. H., Jr., The thermal conductivity of fluids, *Trans. ASME* **76,** 5, 823–830, July 1954.

Apparatus is capable of measuring thermal conductivity of gases (saturated or superheated) and liquids over wide temperature range. Hot-wire method uses two tubes of unequal length but identical in all other respects. Correction for end effects is thus readily obtained. Hot wire, 0.011 in., spaced centrally in glass tubing 0.25 in. inside diameter, is large enough to avoid correction for accomodation of gases, yet small enough to keep radiation correction small. Latter correction, from 2% to 4% in case of measurement of conductivity of air, reported by authors in form of table and plot, calculated by reviewer to be $0.12725 + 0.002275\ (t/100)$ Btu/(hr ft °F). Since authors measured hot wire diameter to only ±0.001 in., reviewer considers results have absolute accuracy no greater than ±3%. Tests were also made of conductivity of furfural in liquid and vapor phases.

Despite enclosure of cell in thermostatically controlled oil bath, entire equipment must be operated in room not subject to rapid temperature changes. Design of apparatus is suitable for static tests to obtain absolute values of thermal conductivity, but it is not designed for control purposes. For intended use, apparatus appears simple and convenient to use. D. Aronson, USA

3513. McChesney, I. G., and Shannon, R. H., The use of benzene as a thermodynamic working fluid for a nuclear power plant, ASME Spring Meet., Baltimore, Md., April 18–21, 1955. Pap. 55—S-29, 7 pp.

Paper presents a feasibility study of benzene as a thermodynamic fluid for the fast breeder reactor. The study was conceived as a possible means of eliminating sodium-water reaction hazards. The material presented should be of interest to anyone concerned with studies of fluids for use as thermodynamic working media.

From authors' summary

3514. Kennedy, G. C., Pressure-volume-temperature relations in water at elevated temperatures and pressures, *Amer. J. Sci.* **248, 540–564, 1950.**

The designer of steam turbines requires thermodynamic tables extended to higher temperatures than most of those at present available. Of the older measurements the most extensive are those of Havlicek and Miskovski to about 400 bars, 475 C, used in the tables of the reviewer; see AMR **7,** Rev. 3707. Author has extended measurements to 2500 bars and 1000 C, made possible by development of new high-temperature creep-resistant alloys. A compressor of Keyes-Benedict (1939) type presses water-vapor into a bomb enclosed in a furnace. Volume, pressure, and temperature are measured.

The results are given in curves and beautiful tables, where the original measurement results seem to be smoothed out. Many of the existing published data on P-V-T relationship at supercritical pressures and temperatures are found to be in considerable error. As the uncertainties in temperature and pressure measurements seem to be larger in author's set of data than in the works of Keyes and his collaborators, he has taken the values up to 460 C and 350 bars from their formulas. Author's measurements confirm these for the first four significant figures.

These measurements should be very important for the setting up of steam tables, if the first four significant figures, or at least three, were correct throughout. According to the author, $(\partial P/\partial T)_v$ should be constant for any values of v, except close to the saturation curve. To test this, reviewer has calculated the quotient in question for different volumes v. The quotient turns out not to be constant. The variations are irregular. Reviewer considers it better to wait for new measurements before making new steam tables. Nevertheless, author has made an interesting pioneer work. O. H. Faxén, Sweden

3515. Weber, W., Temperature dependence of the viscosity of water between 0° and 40°C (in German), *Z. angew. Phys.* **7,** 2, 96–98, 1955.

3516. Phipps, L. W., An adiabatic calorimeter for measuring the specific heats of liquids in the range 0 to 100°C, *J. sci. Instrum.* **32,** 3, 109–113, Mar. 1955.

A calorimeter of the adiabatic type is described, capable of measuring the specific heats of liquids within small temperature intervals (2 or 3 C) over the range 0 to 100 C. An accuracy of ±0.5% can be maintained throughout the full working range, with a small increase in precision between 10 and 30 C. Features of the design include: An electrically heated annular metal jacket; stirring of the calorimetric fluid (125 ml) by an oscillation of the calorimeter about its vertical axis (this has certain advantages over the conventional motor-driven shaft and paddle); a calorimeter heater design giving wide dispersal of heat without local overheating; ease of assembling and dismantling. Primarily designed for measurements on liquid dairy products, it can be used for other liquids. Typical results with the former are illustrated. From author's summary

3517. Barker, J. E., Mott, R. A., and Thomas, W. C., Studies in bomb calorimetry III—Determination of the heat capacity (water equivalent) of a bomb system, *Fuel* **34,** 3, 283–304, July 1955.

It is shown that the term "effective heat capacity" is preferable to "water equivalent." The effective heat capacity is shown to vary not only with the temperature of the water, but also with that of the metallic parts of the calorimeter, a simple formula being given which enables the two opposing effects to be summed and determined values to be referred to a standard temperature. The variation of the caloric value of benzoic acid with the final temperature of the determination, the amount of water in the bomb, and other factors is described. Various steps to improve the repeatability of the determination are discussed, perhaps the most important of which is to bring the final calorimeter temperature ±0.5 C of the jacket temperature.

From authors' summary

3518. Whitaker, J. W., Ghosh, A. K., and Chakravorty, R. N., Air stirring in bomb calorimetry, *Fuel* **34,** 3, 317–320, July 1955.

In attempts to reduce errors in bomb calorimetry due to the heat loss, it was decided to stir the calorimeter water by air bubbling at a steady rate in place of the standard mechanical stirring by reciprocating device or propeller. In order to avoid excessive evaporation loss, which is difficult to allow for accurately, the air was first passed through water at room temperature. The experiments showed that this method of stirring has several advantages, notably in increased accuracy (repeatability) and in general convenience.

From authors' summary

3519. Douglas, T. B., and Dever, J. L., Enthalpy and specific heat of four corrosion-resistant alloys at high temperatures, *J. Res. nat. Bur. Stands.* **54,** 1, 15–19, Jan. 1955.

Specific heats that are believed to be accurate in general to within ±2% are reported for four alloys: from 0 to 900 C for 80 Ni-20 Cr and two stainless steels (type 347, containing 18% chromium, 11% nickel, and 1% niobium, and type 446, containing 26% chromium); and from 0 to 300 C for Monel, containing 67% nickel and 30% copper. These values were calculated from enthalpies measured with a drop method and a precision Bunsen ice calorimeter. The relatively small amounts of heat lost by the alloys as they dropped from the furnace to the calorimeter were estimated and corrections were applied therefor. Discontinuities in specific heat were found only in the case of 80 Ni-20 Cr and the stainless-steel type 446. From authors' summary

3520. Pascal, M. A., Measuring the values of the specific heats of materials used in construction (in French), *Ann. Inst. tech. Bât. Trav. publics* **7,** 77, 372–385, May 1954.

Purpose of this study is to establish the values of the specific heats of materials used in construction and public works.

First, the choice of the test method is discussed: the method adopted is called "the mix method" and involves the use of a Berthelot calorimeter. The fittings used are described and the precision of the measurements is evaluated. This precision, which is approximately 2% in the case of materials of average heat conductance, is 12% when applied to wood. A table of comparative results obtained by this test method is furnished, based on a wide variety of materials. Figures given for each type of material are an average of three tests made.

Paper ends with a table of specific heats of various materials, compiled from data found in French and foreign literature.

From author's summary

3521. Joy, A. S., Methods and techniques for the determination of specific surface by gas adsorption, *Vacuum* **3,** 3, 254–278, July 1953.

A critical review is made of experimental procedures for the determination of specific surfaces and relative surface areas by the method of measuring the volume of gas adsorbed on the surface of the solid. Volumetric and gravimetric techniques are described and compared, and their suitability for routine and research purposes is indicated. The difficulties usually associated with the determination of gas adsorption isotherms are

discussed, and a brief description is given of the methods used for calculating surface areas from the adsorption data.

From author's summary

3522. Erdély, I., On the use of waste heat pumps (in Hungarian), *Magyar Energiagazdaság* **6,** 2, 44–48, 9 figs., 2 tabs., 1953.

Heat pumps have their own particular fields of application; local conditions must be thoroughly investigated in each case. The highest degree of economy can be achieved in countries possessing little or no coal but having at their disposal substantial water power. Increased economy may also be attained if the specific coal consumption required for the production of electric power can be reduced, e.g., from 3800 kcal per kw-h to 2500, which has already been realized at mercury power plants. After explaining the meaning and operation of the waste heat pump on the basis of its entropy diagram deduced from the Carnot diagram, the opinion is advanced that, if waste steam of low temperature must be further heated for industrial or heating purposes, the heat pump system can be recommended only if low upper temperatures are applied. Heat pumps will not always be competitive even in the event that back-pressure steam is available; e.g., they can often be employed economically with evaporators; however, if back-pressure steam can be used in the heating of the latter or if the steam of the last stage can be usefully condensed, the temperature limit of their applicability must always be investigated in advance.

Courtesy of Hungarian Technical Abstracts R. E.

3523. Kimball, D. E., Accuracy and results of steam consumption tests on medium steam turbine-generator sets, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-253, 18 pp.

Precision steam-rate or heat-rate tests on turbine-generator sets assure their owners and builders that the sets equal guaranteed and expected performance. The author's company made such tests on 22 medium-sized sets rated 2500 to 18,750 kw between 1946 and 1952. Most were tested at its plant at Lynn, Mass., on facilities for loads of 15,000 kw or less, with steam up 1500#G and 1000 F.

This paper presents the test methods and results, emphasizing an analysis of their accuracy. This analysis shows: (1) 0.5% uncertainty in manufacturing and factory-testing these sets; (2) 0.3% as the day-to-day uncertainty of tests; (3) 0.17% uncertainty to be charged to the instrumentation of factory tests; (4) probably 0.5% poorer performance of tests in the owner's plants than in factory tests.

This analysis confirms our belief of many years that it is proper to accept or reject a turbine-generator set on the basis of precision tests, with no allowance for test error.

From author's summary

3524. Van Kuyk, H. J. L., Electrical instruments for measuring temperature (in Dutch), *Ingenieur* **66,** 51, 0.110–0.119, Dec. 1954.

A description is given of moving coil and cross coil instruments, automatic potentiometers and bridges, and radiation pyrometers. Some new developments are indicated.

From author's summary

3525. Challoner, A. R., Gundry, H. A., and Meetham, A. R., An electrically calibrated bomb calorimeter, *Phil. Trans. roy. Soc. Lond.* (*A*) **247,** 936, 553–582, Apr. 1955.

After a review of the physical foundations of bomb calorimetry, a bomb calorimeter is described which can be heated electrically or by combustion. The evaporation of water is prevented by sealing the vessel completely. Other modifications in the normal technique are introduced after consideration of (a) the difference in temperature between the outer surface of the calorimeter and the thermometer immersed in it, (b) the effective "boundary" of the calorimeter in electrical and combustion experiments, and (c) variation with temperature of the constants of the apparatus.

The heat of combustion of samples from a batch of thermochemical quality benzoic acid is found to be 26436 J/g under "standard bomb conditions." The standard error of the determination, a combination of errors in reproducibility of electrical and combustion experiments and in measurement of the corrections, is estimated to be 2.2 J/g. From authors' summary

3526. Plank, R., edited by, Refrigeration handbook. Vol. I. Development, economical significance, and materials [Handbuch der Kältetechnik. Bd. I. Entwicklung, wirtschaftliche Bedeutung, Werkstoffe], Berlin, Springer-Verlag, 1954, xviii + 567 pp., 322 figs. DM 84.

This volume I in a series of 12 volumes (volumes 2 and 9 are already available) contains the following chapters: History of production and utilizations of refrigeration, by R. Plank; Economic importance of refrigeration, by O. Wagner; Statistics on production and utilization of refrigeration equipment, by W. Strigel; Meteorologic data, by M. Diem; Building and insulating materials, by I. S. Cammerer, Electrical insulating materials, by O. Herrmann; Metals, by H. Jungblut and F. Hickel; Nonmetallic material, by S. Kresskalt.

In the chapter on history, written by R. Plank in a very fluent and readable style, the discussion of historic developments in thermodynamic sciences like calorimetry, gas liquefaction, the first, second, and third law of thermodynamics, the equation of state, the thermal behavior of mixtures, production of very low temperatures will be of special interest to readers of this magazine. Valuable information is collected on development of refrigeration equipment and utilization, gained by the author through his long personal experience in this field. Meteorologic information contains data on air temperature, humidity, ground temperature, sun radiation over the whole globe. The strength and thermal properties of all materials, which are of interest in refrigeration, are discussed in the required temperature range (down to −200 C). The volume should become a valuable reference book not only for the refrigeration engineer but generally in engineering as well as in applied physics. E. R. G. Eckert, USA

Heat and Mass Transfer

(See also Revs. 3265, 3277, 3338, 3416, 3422, 3425, 3435, 3462, 3505, 3510, 3511, 3513, 3516, 3519, 3520, 3522, 3525, 3526, 3555)

3527. Vodička, V., Conduction of fluctuating heat flow in a wall consisting of many layers, *Appl. sci. Res.* (*A*) **5,** 2/3, 108–114, 1955.

Starting with well-known equations for periodic one-dimensional heat conduction in a slab, author expresses solution in matrix notation. An analogy is then drawn between this special problem and the transmission of electric waves through a passive four-terminal network. Formulas are derived to determine the temperature at any depth in a multilayer infinite wall. All calculations are reduced to multiplying the occurring two-by-two matrixes. Reviewer finds that a more general analogy between transient one-dimensional conduction and the passive four-terminal network was discussed by Pipes [Heat Transfer and Fluid Mechanics Institute, p. 187, June 1954].

R. J. Grosh, USA

3528. Vodička, V., Heat waves in multilayer cylindrical bodies, *Appl. sci. Res.* (*A*) **5,** 2/3, 115–120, 1955.

Starting with well-known equations for periodic radial heat conduction in a hollow cylinder, author expresses solution in matrix notation. Formulas are then derived to determine the temperature at any depth in a multilayer cylindrical body. All calculations are reduced to multiplying the occurring two-by-two matrixes; this task is, in general, difficult. See preceding review.

R. J. Grosh, USA

3529. Korsching, V. H., A direct determination of the thermal diffusion in liquids (in German), *Z. Naturforsch.* **10a,** 3, 242–244, Mar. 1955.

3530. Howling, D. H., Mendoza, E., and Zimmerman, J. E., Preliminary experiments on the temperature-wave method of measuring specific heats of metals at low temperatures, *Proc. roy. Soc. Lond.* (*A*) **229,** 1176, 86–109, Apr. 1955.

3531. Crandall, S. H., The symmetry relations for anisotropic heat conduction, *Physica* **21,** 3, 251–252, Mar. 1955.

3532. Baehr, H. D., Solution of transient heat-conduction problems with aid of Laplace transformation (in German), *Forsch. Geb. Ing.-Wes.* (B) **21,** 2, 33–40, 1955.

3533. van der Leeden, P., The thermal resistances of cubic metals at intermediate temperatures, *Proc. k. Ned. Akad. Wet.* (B) **57,** 3, 317–321, May/June 1954.

It is shown that all data concerning the thermal resistances w of cubic metals at intermediate temperatures ($\Theta/10<T<\Theta$) may be described by a unique function $w_T/w_\Theta F(T/\Theta)$.

From author's summary

3534. Volkenshteĭn, V. S., Method for the determination of thermal characteristics of materials. Part II (in Russian), *Zh. tekh. Fiz.* **24,** 2, 200–204, Feb. 1954.

3535. Tribus, M., and Klein, J., Forced convection through a laminar boundary layer over an arbitrary surface with an arbitrary temperature variation, *J. aero. Sci.* **22,** 1, 62–64, Jan. 1955.

A table of integrating kernels for nonisothermal convection is reprinted from a previous paper by the authors. Additions to and corrections of the original table are included. In addition, explicit instructions are given for computing convection using the table.

R. J. Mindak, USA

3536. Kostyuk, A. G., Temperature fields of turbine disks (in Russian), *Izv. Akad. Nauk Otd. tekh. Nauk* no. 6, 25–36, June 1954.

Determination of temperature field in cooled turbine disks is a substantial part of technical economic calculations in designing arrangements of this kind. Mathematical considerations in this branch of engineering science are rather difficult, reliable formulas and exact physical data are not known, and related problems are often treated under too simplified presuppositions. As a rule, due attention is not paid to such factors as the form of disks, mutual exchange of heat between their parts, the quantity of the cooling air, the influence of the coefficient of heat transfer from disks to ambient cooling air, and many others.

Based on a detailed analysis of his own numerous mathematical solutions of the problem on steady temperature fields in turbine disks, author carefully studies all factors mentioned above. His discussion presupposes reasonable knowledge of the theory of Bessel and hypergeometric functions. Calculations are quite correct and, apart from some minor misprints, reviewer has not found any error in the paper. Of course, resulting formulas are rather complicated and, therefore, reader finds welcome intuitive diagram suitable for technical use.

Paper is doubtless a valuable enrichment of the theory of turbines. It deserves the careful attention of interested specialists.

V. Vodička, Czechoslovakia

3537. Young, R. L., Heat transfer from a rotating plate, ASME Semi-Ann. Meet., Pittsburgh, Pa., June 1954. Pap. 54—SA-51, 11 pp.

Paper contains the results of an experimental investigation into the heat transfer to the laminar flow of air due to the rotation of a solid disk and gives a complete description of the experimental apparatus and procedures. The experiments were performed for thermal differences between 0 and 60 F and for angular velocities of the disk between 0 and 25 radians per sec. A comparison between the experimental results and an approximate theoretical treatment due to Wagner shows discrepancies averaging approximately 25%; the discrepancies are attributed to the presence of natural convection. An empirical equation with Nusselt number given as a function of Péclet number is derived and shown to be in excellent agreement with the experimental results.

Paper also contains a discussion of the theoretical work by Pohlhausen and the reviewer on the same problem; however, author does not appreciate the main points of their work—e.g., its mathematical exactness—and apparently does not understand that the von Kármán solution of the hydrodynamic problem and their solution of the thermodynamic problem are valid only for incompressible fluids; e.g., his belabored discussion of the differences due to their use of the specific heat at constant volume. A reader is advised to omit the author's discussion of the work of Pohlhausen and the reviewer; the remainder of the paper is an important and interesting contribution to the literature on the laminar flow due to a rotating disk.

K. Millsaps, USA

3538. Hofmann, E., Generalized heat-transfer law in turbulent pipe flow and the meaning of dimensionless numbers (in German), *Forsch. Geb. Ing.-Wes.* (*B*) **20,** 3, 81–93, 1954.

Author attempts a general review of earlier work in this field, leading to working equations and plots. Discussion is clear and development generally correct. However, review is limited to central European work, except for a few English and American papers at least 20 years old. As a result, reviewer feels paper is not as complete as many others, including textbook discussions such as that of W. H. McAdams ["Heat transmission," 3rd ed., 205–218, New York, McGraw-Hill, 1954]. The only quantitative addition from recent work is the complex equation of Allenkirch [*Z. Kältetechn.* **5,** S. 253/54, 1953], which is given, but not explained. Particularly poor are the author's values for low Prandtl numbers. He uses the correlation of Elser, which has recently been shown to disagree seriously with the mass of other data now available [*NACA TN* 3336, Mar. 1955].

R. R. Hughes, USA

3539. Izumi, R., On the heat transmission from a rotating disk (in Japanese), *Trans. Japan Soc. mech. Engrs.* **20,** 100, 791–796, 1954.

In the present paper, author tries to study experimentally the heat transmission from a rotating disk to ambient still and moving air.

Two experimental formulas are derived from several experiments; the first one is for the case of natural heat convection and the other, forced convection. For the former case, results are compared with C. Wagner's theory of a rotating disk and the author's experimental result of vertical plate; for the latter case, similar to the author's result for the case of infinite cylinder, the mean Nusselt number N_{sm} is related to the Reynolds number R_e and the Reynolds number due to rotation R_{er} on logarithmic coordinates. From author's summary

3540. Kudryashev, L. I., Extension of the hydrodynamic theory of heat exchange to cases of streamlined objects subjected to drag (in Russian), *Izv. Akad. Nauk SSSR Otd. tekn. Nauk* no. 9, 1309–1316, Sept. 1953.

Author states that an investigation of velocity and temperature traces beyond a body will permit generalization of the hydrodynamic theory of heat exchange in cases of a streamlined body of arbitrary shape, and that generalization for the case of an axially symmetric body presents no serious difficulties.

A theoretical basis is given for an experimental method of investigation of corrections to the hydrodynamic theory of heat exchange for laminar and turbulent traces beyond a body. According to the author, practical use of

$$\overline{K} = [1 - (t/t_0)_{y=0}]/[1 - (\omega_x/W_0)_{y=0}] \cdot [1/Pr^{1/2}]$$

for laminar traces

$$\overline{K} = [1 - (t/t_0)_{y=0}]/[1 - (\omega_x/W_0)_{y=0}]$$

for turbulent traces

in an experimental investigation would be completely straightforward. On this basis it was assumed sufficient to measure the velocity and temperature flux in front of the body and at some distance away from it. The author cites that "numerous works of B. Y. Trubchikov and foreign authors, e.g., Schlichting and others, imply that the distance from the body should be of the order of 2.134 cm and greater than the dimensions of the body being considered." N. M. Matusewicz, USA

3541. Keen, R. D., Experience with graphite as a fabrication material in high-temperature heat-transfer systems, Nuclear Engng. Part I, *Amer. Inst. chem. Engrs., Chem. Engng. Progr. Symp. Series* no. 11, **50,** 45–51, 1954.

Data on the density, gas permeability, and short-time tensile strength of several grades of commercial graphite are presented. It is pointed out that graphite can be machined into intricate shapes, fused to itself or metal, and formed into leak-tight pipe connections. The successful operation of an all-graphite heat-transfer system using liquid tin as a working fluid is described; continuous operation for over 500 hr was possible with peak fluid temperatures ranging from 600 C to 1500 C, and with a maximum fluid velocity of 8 ft/sec. Heat-transfer measurements showed the film conductance between the liquid tin and the graphite wall to be about 6000 Btu/ft² ° F hr. It was found that as the Péclet modulus was increased from about 240 to about 330, the Nusselt modulus decreased from about 16 to about 13, data differing from the theoretical Lyon-Martinelli curve not only quantitatively but in qualitative trend.

L. Green, Jr., USA

3542. Jones, R. H., and Lee, R. E., Testing heat transfer and corrosion of globeiron for fuel cladding in a Na-cooled fast breeder, *Nucleonics* **13,** 2, 70, 72, Feb. 1955.

3543. Gall, W. R., The homogeneous reactor experiment. A pilot-model nuclear power plant, ASME Spring Meet., Baltimore, Md., Apr. 18–21, 1955. Pap. 55—S-15, 6 pp.

3544. Murakawa, K., Heat transfer by free convection in closed, vertical pipes with annular spacing (in Japanese) *Trans. Japan Soc. mech. Engrs.* **20,** 100, 797–802, 1954.

Theoretical analysis and experiments were conducted. Equations of hydrodynamics are solved with eight boundary conditions, and energy equation is reduced to Fredholm's integral equation of the second kind and solved under general surface-temperature distribution of pipe walls. Numerical calculation is accomplished by using the experimental conditions, and the solution is found to coincide with experimental data.

From author's summary

3545. Klinger, V. G., Using light beams for the modeling of radiant heat transfer (in Russian), *Zh. tekh. Fiz.* **24,** 11, 2083–2089, Nov. 1954.

A uniformly lighted sphere was enclosed in another one. The surface of the latter was painted in different shades of gray and a photoelement measured the intensity of light. The obtained results for the density of light radiation compare fairly closely with the calculated results. O. Delatycki, Australia

3546. Okazaki, T., On the effect of the air on film condensation. (2nd Report), *Proc. 1st Japan nat. Congr. appl. Mech.*, 1951; Nat. Committee for Theor. appl. Mech., May 1952, 457–458.

Author develops equations for the concentration gradient of a noncondensable gas across the boundary layer of a condensing vapor in forced convection. He treats both the horizontal and downward flow cases. T. J. Connolly, USA

3547. Parmakian, G., and Sellers, N. S., Superheater metal temperature, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-181, 19 pp.

Paper presents a detailed design procedure for evaluating the several variables involved in the determination of wall temperature of superheater and reheater tubing. Actual measured temperatures are discussed to show the influence of various elements of boiler design and operation on temperature distribution. Methods and locations for making metal-temperature measurements are discussed. From authors' summary

3548. Sterman, L. S., Investigation of heat transer to boiling liquids in tubes (in Russian), *Zh. tekh. Fiz.* **24,** 11, 2046–2053, Nov. 1954.

Presents an empirical dimensionless correlation of author's own work and previous Russian data, applicable in the region of low fractional vaporization. The ratio of experimental Nusselt number to Nusselt number calculated by accepted methods for forced convection of a liquid is found to be a function of a single dimensionless group, $N = (q/r\gamma''w_0)\,(\gamma''/\gamma)^{1.45}(r/cT)^{.33}$ with q heat flux, r latent heat, γ specific weight, w_0 liquid velocity, c specific heat, double prime refers to gas. When this group is less than 0.4×10^{-5}, the ratio of Nusselt numbers is unity; when the correlating group is larger the ratio of Nusselt numbers is proportional to the 0.7 power of the group. The correlation predicts data on water at 2 to 7 atm pressure and ethyl alcohol at 11 to 52 atm within about ±20%. The range of variables represented is: heat flux, 0.05 to 1 million kcal/m² hr; velocity, 0.2 to 6.7 m/sec; tube diameter 16 mm.

The paper suffers from failure to explain whether the heat-transfer coefficients discussed are local or average values and the exact way in which they are calculated. Comparison of the correlation with non-Russian data is also lacking.

C. V. Sternling, USA

3549. **Nishikawa, K., Effect of surface roughness on boiling heat transfer** (in Japanese), *Trans. Japan Soc. mech. Engrs.* **20**, 100, 808–815, 1954.

Experiments were carried out with distilled water boiled on horizontal heating surfaces, fitted with various shapes of concentric grooves of triangular cross section. It was found that the mean height was adequate to the scale of roughness on the boiling heat transfer. Further, by introducing a new "coefficient of foaming," which represents the foaming ability of both heating surface and boiling liquid, experimental formulas on the heat transfer in the nucleate boiling are derived.

From author's summary

Combustion

(See also Revs. 3292, 3293, 3418, 3448, 3496, 3517, 3525)

3550. **Klein, G., Equations of a simple flame solved by successive approximations to the solution of an integral equation. Part III,** *Univ. Wisc., Nav. Res. Lab., Dept. of Chem., Ser.* 8, SQUID-2, 61–97, Feb. 1955.

In this article, an ideal flame with simple chain reaction is treated, as an extension of a previous publication. Several methods of solution are given and numerical results are tabulated. For details see AMR **8**, Rev. 1518. C. Franze, Germany

3551. **Summerfield, M., Reiter, S. H., Kebely, V., and Mascolo, R. W., The physical structure of turbulent flames,** *Jet Propulsion* **24**, 4, 254–255, July/Aug. 1954.

Turbulent flames, similar to those occurring in ramjet combustors, were examined experimentally under idealized conditions. Measurements were made of the OH, CH, and H_2O spectral emission distributions, of the fluctuations in the flame electrical conductivity, of the temperature distribution, and of the apparent sizes of the inhomogeneities in the flame zone.

Authors conclude that the results show that theories which treat turbulent flames as being wrinkled laminar flames cannot be correct. It is claimed that all their measurements suggest a distributed reaction zone, and that this concept has been used satisfactorily in a theory of turbulent flame propagation.

Paper itself is a brief summary; a fuller report is promised. Reviewer believes that this should provide a valuable basis for further discussion. J. Barr, Scotland

3552. **Westenberg, A. A., Flame turbulence measurements by the method of helium diffusion,** *J. chem. Phys.* **22**, 5, 814–823, May 1954.

Author describes experiments employing thermal conductivity detection methods for flame-generated turbulence following a variety of stabilizers in a 5-cm × 20-cm rectangular duct, using pentane-air mixtures. Considerable care was taken to ascertain effects of water and size of helium source, injection and sampling rates, etc., so that data may be interpreted confidently. Results show that technique is successful and sensitive to small changes of intensity, but gives magnitudes which are probably too high due to disturbance of source. Main result indicates that flame-generated turbulence is not so pronounced as might have been expected. Very careful analysis of limitations of the work is given. D. G. Shepherd, USA

3553. **Goldsmith, M., and Penner, S. S., On the burning of single drops of fuel in an oxidizing atmosphere,** *Jet Propulsion* **24**, 4, 245–251, July-Aug. 1954.

This is an extended and generalized analysis of the work by G. A. E. Godsave for the burning process of droplets. Principal assumptions are as follows: The flame front is spherical; the delivery rates of fuel and oxygen are in stoichiometric proportion; the reaction rate at the flame front is fast compared with the delivery rate of combustible gas. This method of analysis utilizes only integrated forms for energy and continuity equations. By this simplicity authors are able to derive an expression for the mass flow rate of fuel without introducing the approximations used in the analysis by Godsave, namely, that thermal conductivity and specific heat of fuel vapor are independent of temperature. Results of this analysis provide a good agreement with Godsave's experiment.

S. Kumagai, Japan

3554. **Kobayasi, K., A study of the evaporation and combustion of a single droplet (2nd Report: Evaporation velocity)** (in Japanese), *Trans. Japan Soc. mech. Engrs.* **20**, 100, 831–837, 1954.

An attempt is made to study the evaporation of a single liquid droplet hung by a quartz fiber, by recording on motion pictures. The evaporation of twelve pure liquids, five blends, and petroleum fuels—water, methylalcohol, ethylalcohol, benzene, toluene, nitrobenzene, cyclohexane, n-hexane, n-heptane, isooctane, cetane, methylnaphthalene, water-methylalcohol blend, motor gasoline, kerosene, diesel light oil, and heavy oil—was studied. As the derivative of the square of the diameter of the droplet with respect to time is a constant value for pure liquid and it is satisfactorily proved that the life of the droplet is proportional to the square of its initial diameter for blends or petroleum fuels, it may be convenient to represent the rate of evaporation velocity by that constant, which may be called the "coefficient of evaporation velocity of droplet." The results are compared with the theory, and satisfactory agreement is obtained.

From author's summary

3555. **Ott, H. H., Measurements on oil flames** (in German), *ETH* no. 13, 106 pp., 1954.

This experimental work on the upright flame of diesel-gas oil is composed of two parts. First part treats the combustion of air-atomized flame whose ξ = (*amount of primary air*)/(*theoretical amount of air*) assumes 12 different values. Flame shapes, the temperature and velocity distribution, and total radiation were investigated. The experimental results and the degree of completeness of combustion, calculated from the former, proved they may generally be represented as functions of ξ.

Second part treats the combustion of pressure-atomized flames in an open tube. The results indicate that the local excess air rate is correlated with the temperature at the corresponding point.

The radiation and heat balance in the combustion chamber were investigated and the relation with the excess air rate discussed, although the excess air rate variation was limited, regrettably, to only three values.

Probably this work was carried out for the purpose of basic research for gas turbines or jet-propulsion mechanisms, but reviewer believes that the simple but well-investigated devices and the careful discussion would be promising in the study of the flames in other industries. F. Jinno, Japan

3556. **Stemann, H., Investigation on the significance of spontaneous ignition upon the knock effect in Otto engines** (in German), *Forsch. Geb. Ing.-Wes.* (*B*) **21**, 1, 1–8, 1955.

F. A. Schmidt's expression for the delay period $z = a \cdot \beta \cdot (T)^{1/2} \cdot e^{b/T} \cdot p^{-n}$ and his formula for the reaction velocity $dB/dt = d \cdot p^n/e^{b/T}(T)^{1/2}$ are used to determine the onset of knocking. Relatively good agreement between calculated and observed values was obtained. Observations from a large number of CRO diagrams were used to establish conditions in the end gas.

Naturally, some estimations have been made in evaluating the many constants in Schmidt's expressions, but the consistency and general form of the graphs do support the assumptions made. Although the reported results refer to benzene only, author hopes that fuel with 2-stage reactions can be studied in the same way. The importance of the time element in the study of knocking combustion (Taylor, Leary, and Livingood at M.I.T.) is supported by this work. M. Rand, Canada

3557. Yellott, J. I., Broadley, P. R., Mayer, W. M., and Rotzler, P. M., Development of pressurizing, combustion, and ash separation equipment for a direct-fired coal-burning, gas turbine locomotive, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-201, 37 pp.

Acoustics

(See also Revs. 3265, 3408)

3558. A discussion on the first and second viscosities of fluids (under the leadership of Rosenhead, L.); Rosenhead, L., Introduction. The second coefficient of viscosity: a brief review of fundamentals; Doak, P. E., Vorticity generated by sound; Richardson, E. G., Acoustic experiments relating to the coefficients of viscosity of various liquids; Davies, R. O., Kinetic and thermodynamic aspects of the second coefficient of viscosity; Taylor, G., The two coefficients of viscosity for an incompressible fluid containing air bubbles; Taylor, G., Note on the volume viscosity of water containing bubbles; Davies, R. O., A note on Sir Geoffrey Taylor's paper; Kneser, H. O., Transport and relaxation phenomena; Piercy, J. E., and Lamb, J., Acoustic streaming in liquids; Andreae, J. H., and Lamb, J., Ultrasonic measurements and the second viscosity of carbon disulphide; Meixner, J., On the thermodynamic theory of the second viscosity; Karim, S. M., Experimental determination of the second viscosity; Oldroyd, J. G., Note on the hydrodynamic and thermodynamic pressures; Truesdell, C., The present status of the controversy regarding the bulk viscosity of fluids; Andrade, E. N. da C., Review of discussion; *Proc. roy. Soc. Lond.* (*A*) **226,** 1164, 1–69, Oct. 1954.

The stress tensor for a viscous fluid in the Navier-Stokes formulation is $S = (-p + \lambda D_I)I + 2\mu D$, where D is the rate of deformation tensor, D_I its first scalar invariant in the expansion, and I is the idemfactor. Here μ in the first (or ordinary) coefficient of viscosity, measuring shear viscosity or resistance to change of shape, while λ (denoted by μ' in this series of papers) is the second coefficient. Questions regarding the determination of μ' form the main subject of the discussion. According to Andrade, the basic hydrodynamic difficulty lies in the fact that μ' is not, in the ordinary sense, a physical constant in that no experiment can be devised, even in thought, to measure μ' directly. In the classical theory it is customary to define the pressure p by $-3p = S_I$, the first scalar invariant of S, which leads at once to

$$K = \tfrac{1}{3}(2\mu + 3\mu') = 0$$

where K is the bulk viscosity. There is experimental evidence that $K = 0$ for monatomic fluids, but there is certainly no evidence that the relationship is universally true. Taylor, in his investigation of an incompressible fluid containing air bubbles, finds the value $\mu' = 4\mu/3v$, where v is the small proportion of the total volume occupied by the bubbles.

Experiments based on measurements of sound absorption and on acoustic streaming give values of μ'/μ as high as 200 (carbon disulphide). On the other hand, it is not at all clear that these experiments can legitimately be interpreted in the desired sense; indeed, other explanations in terms of sound attenuation and relaxation can be advanced. Truesdell remarks that the solutions for acoustic streaming are controversial. The only evidence that can be conclusive here is a mathematical approximation theorem stating precisely the position of solutions of the presumably approximate equations with respect to the corresponding exact solutions. We seem to be far from any such theorem at present, and all existing results on acoustic streaming must be viewed with a wary eye. It is interesting to notice that the only approach to the streaming problem is through hydrodynamics. This puts that group of physicists who deny the correctness of the hydrodynamical theory of absorption and dispersion in the rather odd position of rejecting the first-order hydrodynamic perturbation equations but accepting those of the second order. No test of any of the theories is afforded by experiments which stay within the linear absorption range.

It is to be hoped that this series of able papers will urge more workers to enter this important field of research.

L. M. Milne-Thomson, England

3559. Lassiter, L. W., and Heitkotter, R. H., Some measurements of noise from three solid-fuel rocket engines, *NACA TN* 3316, 21 pp., Dec. 1954.

Results of a systematic experimental investigation of the sound field of one type of rocket engine are given. These comprise frequency spectra and over-all pressure data as obtained along a semicircle of 50-ft radius about the engine. The spectra are shown to be of random nature and the angular distribution is shown to have a maximum at an angle of about 45° off the jet axis downstream of the nozzle. Frequency spectra and over-all pressure magnitudes are also given for a few isolated points in the sound fields of two other solid-fuel rockets.

From authors' summary

3560. Hubbard, H. H., and Lassiter, L. W., Some aspects of the helicopter noise problem, *NACA TN* 3239, 14 pp., Aug. 1954.

Some aspects of the helicopter noise problem are briefly discussed. These discussions deal with the nature of the problem, some tentative criteria for use in evaluating it, and the physical characteristics of noise from helicopters. Over-all noise data are presented for a reciprocating-engine helicopter along with discussions of the characteristics of noise from its various components such as the engine, gearing, and rotors. Some consideration is also given to the noise from tip jet rotor systems.

From authors' summary

3561. Elwell, F. S., Experiments to determine neighborhood reactions to light airplanes with and without external noise reduction, *NACA Rep.* 1156, 43 pp., 1953.

Supersedes article reviewed in AMR **6,** Rev. 1081.

Ballistics, Detonics (Explosions)

(See Revs. 3294, 3507, 3586)

Soil Mechanics, Seepage

(See also Revs. 3436, 3437)

3562. Öllös, G., Investigation of seepage in nonhomogeneous soil under structures (in Hungarian), *Hidrológiai Közlöny* **35,** 1/2, 3/4; 1–5, 117–126, Jan./Feb., Mar./Apr. 1955.

Paper describes seepage studies carried out in a flume with 14 different models, varying sheet-pile lengths and thickness of soil layers with different permeability coefficient and with horizontal and dipping surfaces. Author displays in tables and graphs the

detailed test results—distribution of potentials, gradients, shape of flow lines, seepage velocities, and quantities of seepage—and gives critical comments and comparisons with the case of homogeneous ground. Some important qualitative statements have been fixed: There exists an unfavorable condition for the structure when (a) soil with lower permeability prevails in the downstream side; (b) the tip of the sheet piles comes closer to the stratum with lower permeability; (c) the uppermost layer in the seepage space is less permeable than the lower part.

Á. Kézdi, Hungary

3563. Pilatovskii, V. P., Filtration of a fluid in an imperfect stratum (in Russian), *Izv. Akad. Nauk Otd. tekh. Nauk* no. 4, 121–132, Apr. 1954.

Author defines imperfect stratum as containing either impermeable isolated regions around which filtration occurs or isolated bands filled by stratified (incompressible) fluid. These isolated regions are called lenses or cavities. Sandy strata contain isolated clayey lenses which affect bore-hole operation, while limestone strata have bands (cavities) through whose walls fluid oozes without being absorbed and, if these cavities are large enough, the bore-hole operation is also affected. Imperfect stratum is considered as limit case of inhomogeneous stratum with individual isolated regions having permeability 0 or ∞, while remainder of region has constant permeability.

Filtration problems in imperfect strata are solved assuming (1) flow around each lens and through each cavity is without circulation, and (2) fluid discharge through boundary of each cavity is zero. Problems are solved by forming impermeable regions as a result of action of separate dipoles on the basic filtration flow; in more complex cases, continuous distribution of dipoles is used. Method is applied to following examples: (1) Determination of bore-hole debit in an imperfect stratum; (2) effect of elliptic lens on bore-hole debit; (3) effect of elliptic cavity on bore-hole debit; (4) imperfect bore-hole in shape of slot filter.

Author concludes that solutions of above problems permit finding upper and lower bounds of the desired quantities for more complex isolated inhomogeneities in strata.

M. D. Friedman, USA

3564. Numerov, S. N., One method of solving filtration problems (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 4, 133–139, Apr. 1954.

Author describes fourth method of conformal mapping useful in problems of filtration, which does not rely on using hodograph velocities. The method is illustrated by solving the problem of filtration from a furrow-type irrigation ditch with evaporation from the free surface of the ground water.

M. D. Friedman, USA

3565. Pilatovskiĭ, V. P., Interaction of round concentric galleries with draining layers in elastic conditions (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **15**, 147–158, 1953.

A rigorous solution of the problem is given in this paper. The solution is based on the consideration of pressure function $h(\rho,\tau)$, ρ and τ being dimensionless parameters of length and time, respectively. This function is tabulated, which permits numerical treatment of the problem of interaction of galleries. Incidentally, the problem of external and internal influx of the fluid to a round gallery is also considered.

From author's summary by D. Radenković, Yugoslavia

3566. Nomachi, S., Studies of pavement slabs by the thin-plate theory, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 131–134.

Author regards a concrete pavement slab as a classic thin plate, loaded on top face in a prescribed manner and on bottom face by a linear unidirectional elastic subgrade such that negative (uplift) reactions are possible.

Using Green's transformation, general double Fourier series solution is generated.

Solution is applied in detail to a square slab loaded over a small square region at one corner. All edges of slab are treated as completely free. Deflections, stresses, and moments are computed and graphed, and stresses are compared with corresponding experimental results. Agreement is to within 7% for maximum stress, the average being nearer 10%.

F. S. Shaw, Australia

3567. Danilyuk, A. M., Calculation of foundation settlement on laminated stratified soils (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 6, 87–96, June 1954.

Approximate computation of rigid foundation settlement on laminated stratified soil of variable compressibility (including rock surface) starts with formulas for settlement of equivalent layers of homogeneous elastic foundation. Formulas for settlement of rigid and flexible slabs are combined and trimmed in accordance with more exact solutions of other authors. Necessary coefficients for numerical computations are given. Author gives two numerical examples and points out that his solution gives as precise results as more exact ones, whereas his method is more universal. In the introduction, a review of solutions used in USSR is given.

V. Mencl, Czechoslovakia

Micromeritics

(See Revs. 3294, 3500)

Geophysics, Meteorology, Oceanography

(See also Revs. 3438, 3526)

3568. Möller, F., Radiation in the neighborhood of the ground (in German), *Z. Meteor.* **9**, 2, 47–53, Feb. 1955.

The long-wave radiation exchange between the ground and the atmosphere is evaluated for one 24-hr period, using temperature observations at 0, 10, 20, 40, 160, and 640 cm above ground level. For each hour the rate of change in air temperature at these heights due to long-wave radiation is determined by subtracting the effects of convection, evaporation, solar radiation, and conduction in the ground. It is shown that during the daytime the long-wave radiation causes strong cooling (as much as 26 C/hr) of the air layer a few mm thick immediately adjacent to the earth, while at 10 cm above the ground and higher an increase in air temperature (as much as 18 C/hr) occurs. During the night the reverse happens. A full discussion of the reasons for this phenomenon is given.

A. Whillier, South Africa

3569. Haarlaender, H., Flow-field divergence and surface pressure change (in German), *Meteor. Rdsch.* **7**, 11/12, 201–203, Nov./Dec. 1954.

Horizontal divergence is expressed in natural coordinates. Latitude and curvature effects being ignored, formula is developed for calculation of streamline-spreading term of horizontal divergence in terms of height of pressure surface at four neighboring points. Practical utility of technique is not demonstrated.

W. A. Baum, USA

3570. Biggs, J. M., Namyet, S., and Adachi, J., Wind loads on girder bridges, *Proc. Amer. Soc. civ. Engrs.* **81**, Separ. no. 587. 24 pp., Jan. 1955.

3571. Minnesota International Hydraulics Convention, Proceedings, Part II. Waves, beach erosion, and hydromechanics of shore structures, Inter. Assn. Hydr. Res. Hydraulics Div. Amer. Soc. civ. Engrs.; Univ. Minn., Minneapolis, Minn., 173–302, Sept. 1953.

Section consists of following articles:

(A) Basic experimental wave research,* F. Suquet and A. Wallet, (B) Investigation of the effect of resonant structures on wave propagation,* J. Valembois; (C) Table Bay as an oscillating basin, B. Wilson; (D) Wave-damping effect of beaches, J. Healy; (E) The influence of a vertical wall on a beach in front of it, R. Russell and Sir Claude Inglis; (F) Beach erosion in Japan, K. Aki; (G) The effect of waves on a sand beach, H. Flinsch; (H) Effect of distortion on sea-hydraulic models with movable bed,* L. Levin and M. Voyinovic; (I) Design of rock-fill breakwaters, P. Hedar; (J) Experimental study of wave overtopping on shore structures, T. Saville, Jr. and J. Caldwell; (K) The Wellawatte Canal outlet in Ceylon, T. Mylvaganam and W. Paranathala; (L) A multi-purpose wave generator, Lt. C. Coyer; (M) A continuous recording point gage for the measurement of surface waves, W. Baines and I. Smith.

(* denotes paper is in French.)

(A) describes experimental techniques and results of experiments on main dimensions of particle trajectories in standing and progressive waves, wave celerity, and limit waves and clapotis. Results are used to test theories of Stokes, Miche, and the investigators. Agreement with theory is generally good. (B) discusses use of resonating structures placed along path of wave propagation. The resonator acts as a reflector for certain waves without obstructing passage. Method gives encouraging results in some model studies. (C) investigates possible causes of oscillations of Table Bay, South Africa. Some of the periods observed correspond to natural periods of South Atlantic Basin lying outside bay. Treatment of bay by means of various geometrical configurations gives certain natural periods which may be excited by certain incoming long waves. Experimental model of Table Bay and harbor confirms results. (D) gives results of experimental work on energy loss in incident waves on sloping beaches. Results give values of reflection coefficients as functions of beach slope and wave steepness. Beaches with slopes less than 10° are found important energy absorbers. Initial wave steepness is found to be important for steepness ratio less than 0.01. Authors do not consider results with slopes in excess of 30° to be too accurate. (E) Two-dimensional model sand beaches were built up to natural profile by wave action. A vertical sea wall was then inserted and beach fell slowly at first and then more rapidly until a more stable profile was reached. Possible applications to natural beaches are discussed. (F) discusses various examples of beach erosion in Japan. (G) theoretically determines criteria for beach building by wave action. Experiments indicate that slope of beach is governing factor. (H) discusses difficulties obtaining similitude in model studies of shore currents and sediment transport. (I) investigates criteria for rock-fill breakwaters. Two theoretical formulas with experimental constants for weight of stones are given in terms of wave heights, slope of breakwater, and density of stones. Constants in equations are computed. Comparisons of model damage and actual cases are made. (J) Dimensional analysis of overtopping gave various dimensionless parameters. Effect of these parameters on volume of water overtopping vertical planes of different heights for a beach slope of 10° is shown. Parameters involved were wave characteristics, height of structure, and depth of water at structure. Cases of breaking and nonbreaking waves and parameters important in each case are discussed. Data summary is presented. (K) discusses use of jetties to alleviate sand-bar formation at canal outlet. Model experiments indicated hooked jetties would decrease formation. So far, straight jetties have succeeded in lengthening time between bar formation. (L) reports on design, fabrication, and testing of wave generator which is claimed to be rugged and economical and capable of approximating all types of waves useful in model studies. (M) A probe which measures water levels to within 0.001 ft and responds to changes of 0.15 ft in 1/10 sec is discussed. Theoretical solution of probe motion is compared with instrument characteristics.

W. P. Elliott, USA

3572. Matumoto, Tosimatu, and Sato, Y., On the vibration of an elastic globe with one layer. The vibration of the first class, *Bull. Earthq. Res. Inst. Tokyo Univ.* **32,** 247–258, 1954.

Using Sezawa's form of solutions in the problem of vibrations of an elastic sphere [title source, **10,** 299–334, 1932], the change of the period caused by a variation of elastic constants and density is investigated. The transverse vibrations are considered in the layered earth under assumption of a rigid or liquid core and of a solid mantle. In these two cases the period equation takes a simpler form and some of its roots are evaluated.

W. S. Jardetzky, USA

3573. Matuzawa, Takeo, and Hasegawa, H., Field theory of elliptical earthquakes: Elliptical wave region, *Bull. Earthq. Res. Inst., Tokyo Univ.* **32,** 231–246, 1954.

The boundary conditions for an elliptic plate are formulated as follows: $p_{xx} = p_{xz} = p_{yz} = 0$ at $z = -h$; $p_{zz} = -p$, $p_{xz} = p_{yz} = 0$ at $z = h$ and $u = v = w = 0$, $\partial w/\partial n = 0$ at $z = 0$ and $x^2/a^2 + y^2/b^2 = 1$. Using Love's method for this problem, the static displacements are obtained in the form of polynomials in x, y, z. The horizontal shear at the free surface as well as the stresses at the bottom of the plate are estimated for $b = 2h$, $a = 4h$, $\sigma = 1/4$, and the plate is considered as an elliptic source of an earthquake.

W. S. Jardetzky, USA

Lubrication; Bearings; Wear

3574. Eldredge, K. R., and Tabor, D., The mechanism of rolling friction. I, The plastic range, *Proc. roy. Soc. Lond.* (*A*) 229, 1177, 181–198, Apr. 1955.

Paper deals with the friction and surface damage produced when a hard steel sphere rolls between flat parallel surfaces of a softer metal. By means of a rolling-friction apparatus, which is extensively described, experimental data were obtained for low rolling speeds (0.5 – 100 cm/sec) over a very wide range of loads.

Lubricants proved to have little effect on the resistance to rolling. When rolling first starts, the resistance is primarily due to plastic displacement of metal ahead of the ball and it is shown how it may be calculated in terms of the area of the grooved track and the yield pressure of the metal. With successive traversals there is a slow increase in groove width, a slight change in track curvature, and a gradual decrease in rolling resistance until an equilibrium stage is reached. A study of the deformation produced during rolling shows that the center of the grooved track is very heavily sheared in the direction of rolling and, with repeated traversals, this may lead to fatigue of the metal. If the equilibrium stage is reached, the whole of the load is born by the ellipse of contact formed by elastic deformation within the width of the existing track.

J. F. Besseling, Netherlands

3575. Tabor, D., The mechanism of rolling friction. II, The elastic range, *Proc. roy. Soc. Lond.* (*A*) **229,** 1177, 198–220, Apr. 1955.

When a metal cylinder rolls over a rubber surface, different ele-

ments of the surface within the region of contact are stretched, elastically, by different amounts; this differential elastic stretching leads to microslip with corresponding dissipation of frictional energy, as has been pointed out by Reynolds. Present paper proves by experimental evidence that this type of interfacial slip is totally insufficient to account for the observed resistance to rolling. It is shown quantitatively that, under these conditions, the rolling resistance may be derived from the elastic hysteresis losses in the rubber, which is in agreement with the fact that lubricants are ineffective in reducing the rolling friction. Similar results are obtained for hard spheres rolling on rubber surfaces. If, however, a sphere is rolled in a preformed rubber groove, interfacial slip may occur, since the central band on the ball measures out a larger circle than the bands at the edges of the groove. Of this type of slip, first described by Heathcote, a simple quantitative theory is given. When the groove is deep and of a curvature very close to that of the ball, this type of slip is very marked, and a suitable lubricant can effect a considerable reduction in the rolling resistance.

If the rolling friction of a hard steel sphere in the equilibrium groove formed in the surface of a softer metal is attributed to hysteresis losses, large loss factors, greater than 20%, must be involved, for example, for copper surfaces. On the other hand, rolling friction of the Heathcote type would imply impossibly high coefficients of friction, even in the presence of the best lubricants. Experiments in which a copper ball was rolled over an identical copper ball showed the equilibrium rolling friction to be as high as that observed when a hard steel sphere rolls in a copper groove, though because of symmetry conditions at the region of contact both the Reynolds and the Heathcote type of slip are eliminated.

It is concluded that interfacial slip contributes little to the rolling friction and, consequently, lubricants may reduce the amount of wear, but have little effect on the rolling resistance. However, if the elastic hysteresis losses shall be responsible for the resistance to rolling, the large loss factors which are required should be explained, in reviewer's opinion.

J. F. Besseling, Netherlands

3576. Goodzeit, C. L., Roach, A. E., and Hunnicutt, R. P., Frictional characteristics and surface damage of thirty-nine different elemental metals in sliding contact with iron, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-53, 8 pp.

Paper describes an experimental investigation of the friction and surface-damage characteristics of iron in sliding contact with various elemental metals without lubrication. No simple, direct relationship was found between the value of the coefficient of sliding friction and the characteristics of the material transfer between metals. It was found that the surface-damage characteristics are related to the relative hardness of the metals in sliding contact, their mutual solubility, and their ability to form intermetallic compounds. From authors' summary

3577. Mahncke, H. E., and Tabor, W., A demonstration of Bingham type flow in greases, *Lubrication Engng.* **11,** 1, 22–28, Jan./Feb. 1955.

See AMR 8, Rev. 654.

3578. DuBois, G. B., Ocvirk, F. W., and Wehe, R. L., Experimental investigation of misalining couples and eccentricity at ends of misalined plain bearings, *NACA TN* 3352, 81 pp., Feb. 1955.

An experimental investigation was conducted to study the behavior of full journal bearings under steady load when acted on by a steady misaligning couple. Displacements of the ends of the journal axis were measured with either an axial couple applied in the plane of the central load or a twisting couple in the plane normal to the central load. Oil-flow-rate and bearing-temperature measurements were also made to determine the effect of misaligning couples on these quantities.

From authors' summary

3579. Barwell, F. T., Milne, A. A., and Webber, J. S., Some experiments on oscillating bearings, *Trans. Instn. Engrs. Shipb. Scot.* **98,** part 5, 267–326, 1954/1955.

Oscillating bearings subjected to a unidirectional load operate under conditions of boundary or mixed lubrication, and their performance is consequently affected by material and lubricant properties to a much greater extent than other types of oil-film bearings. Such bearings are frequently encountered in reciprocating mechanisms, though the best known situation is that of the piston pin in two-stroke engines.

Paper presents results of extensive experiments on performance of 2-in. diameter bearings of bronze and lead and tin babbitt oscillated through angles from 14° to 44° at frequencies of 30 to 800 cpm while subjected to unidirectional loads up to 10,000 pounds. Data are presented on instantaneous friction force, temperature, wear, resulting shaft roughness, oil flow, and oil pressure distribution.

Friction and wear results indicate that bearing operation is at least partially dependent upon hydrodynamic oil films. Suitable grooving is necessary to permit entrance of oil between the shaft and bearing in the loaded area. Smooth surfaces and good conformity are essential for satisfactory operation. Bearing wear appeared to increase continuously in endurance tests with babbitt and some extrusion occurred. Shaft wear was reduced by factor of 3 by using one helical groove rather than two circumferential. Friction became smaller with increased frequeny of oscillation. Bronze bushing suffered slight initial wear and then appeared to wear no more during endurance run. Experiments with uncompounded oil demonstrated appreciable impairment of performance of lead base babbitt and bronze.

Reviewer's experience confirms influence of grooving, bearing material, and lubricant upon performance of oscillating unidirectionally loaded bearings. Journal material and specific chemical composition of oil additives are also critically important even with babbitt bearing material. Grooves continuous from edge to edge of bearing, circumferentially spaced to equal angle of oscillation, have proved most suitable.

J. B. Bidwell, USA

3580. Wepfer, W. M., Water-lubricated bearing development, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-121, 12 pp.

3581. Fogg, A., and Webber, J. S., The influence of some design factors on the characteristics of ball-bearings and roller-bearings at high speeds, *Instn. mech. Engrs.*, 3–18, 1955.

Paper describes investigations into the performance characteristics of ball bearings and roller bearings running under conditions similar to those encountered in gas turbines. The majority of the work was carried out on ball bearings, suitable for shafts of 2-in. diam, which were run under various combinations of radial load and thrust load. Modifications were made to diametral clearance and track curvature of the bearings and to the material, design, and dimensions of the cages. The effects of these on bearing performance are given and discussed. Investigations on larger (5-in. bore) bearings indicate additional precautions necessary with this size. Work on roller bearings was confined to the 2-in. size and the variables investigated included diametral

clearance of bearing and end clearance of rollers. An interesting comparison is provided by the performance of a cageless roller bearing. From authors' summary

3582. Rao, R. S., and Nigam, S. D., The effect of cross viscosity on the performance of full journal bearings without side-leakage, *ZAMP* **5,** 5, 426–429, 1954.

Problem of full journal bearing is investigated for non-Newtonian liquid involving existence of stress in directions across velocity gradient depending on coefficients of "cross viscosity." Governing equations are rederived and analyzed and show that the attitude angle is 90° when cross viscosity is neglected. Effect of cross viscosity is to make attitude angle greater, as is observed in practice and usually explained as due to side leakage. However, solution presented here neglects side leakage.

C. F. Kettleborough, Australia

3583. Clark, G. H., Marine lubrication, *Trans. Inst. mar. Engrs.* **66,** 10, 229–276. Oct. 1954.

Author briefly covers the refining of lubricating oils, laboratory tests and their significance, the use of additives, the fundamental principles of lubrication, and lubrication problems associated with reciprocating steam engines, geared steam turbines, and diesel engines. From author's summary

Marine Engineering Problems

(See also Revs. 3495, 3583)

3584. Almy, N. V., and Hughes, G., Model experiments on a series of 0.65 block coefficient forms. Part I, The effect of variations in *LCB* position and bilge radius on resistance and propulsion, *Quart. Trans. Instn. nav. Arch. Lond.* **96,** 4, 377–427, Oct. 1954.

Paper describes tests carried out at the National Physical Laboratory for the British Shipbuilding Research Association on a methodical series of models of fast merchant ship form of 0.65 block coefficient. Objective was (a) to determine effect on resistance of systematic variations in longitudinal center of buoyancy and of bilge radius and (b) to determine effect on propulsive efficiency of *LCB*, three different propellers being used.

Results, presented for 400-ft ship, indicate that effect of bilge radius is generally small and irregular, optimum radius being about 8 ft. Effect of *LCB* location is such that most economical speed is 15 knots for *LCB* at $^1/_2$% of *LBP* forward of amidship, increasing to 17 knots for *LCB* at $1^1/_2$% *LBP* aft. Effect of *LCB* on *QPC* is small; the latter, however, increases with propeller diameter.

Paper presents rather complete and well-organized data. Unfortunately, value of conclusions does not correspond to magnitude of effort. Absence of turbulence stimulation in the majority of tests renders conclusions somewhat doubtful. (Some complementary tests to verify effect of turbulence stimulation on resistance were carried out at Clydebank; see following review.) Effect of bilge radius is small and difficult to appraise for changes thereof were coupled to changes in the curve of sectional areas. Effects of *LCB* location and propeller diameter are in keeping with already well-known results. M. St. Denis, USA

3585. Ferguson, J. M., and Meek, M., Model experiments on a series of 0.65 block coefficient forms. Part II, The effect on resistance of variations in breadth-draught ratio and length-displacement ratio, *Quart. Trans. Instn. nav. Arch. Lond.* 96, 4, 428–466, Oct. 1954.

Paper gives results of additional tests carried out at John Brown in Clydebank and National Physical Laboratory on the series discussed in preceding review. Objectives of these tests were to determine effect on resistance of (a) varying beam-draft ratio (2.12–3.43) at constant length-displacement ratio (5.56) and (b) varying length-displacement ratio (4.33–6.34) at constant beam-draft ratio (2.12).

Results show resistance increases with beam-draft ratio up to critical, then decreases; resistance also decreases with increasing length-displacement ratio. First effect is greater at lower, second effect greater at higher speed-length ratios. Paper is well presented like the previous one. Since turbulence stimulation was used (maximum effect 8%), results are more reliable. Except for apparent anomaly of decreasing resistance at high beam-draft ratios, results are in accord with presently accepted ideas.

M. St. Denis, USA

3586. Wenk, E., Jr., The prediction of dynamic performance of full-scale gun turrets from static tests of small-scale models, *Proc. Soc. exp. Stress Anal.* **11,** 2, 115–132, 1954.

A truss-type gun girder, used for the first time on the Salem class of cruisers, was checked for structural strength by static tests of a $^1/_{10}$-scale model, and later by static and dynamic tests of a full-scale pilot turret and by shipboard firing trials.

Results have been analyzed to determine the accuracy of prediction of the small-scale models and the validity of adopting a dynamic load factor in design based on the assumption of dynamic response in one degree of motion only.

From author's summary

3587. Doust, D. J., Side launching of ships—with special reference to trawlers, *Quart. Trans. Instn. nav. Arch. Lond.* **97,** 1, 80–105, Jan. 1955.

Over the past few years an investigation into the side launching of ships has been in progress at the Ship Division of the National Physical Laboratory. Ship launches have been recorded by means of gyroscopic equipment placed on board and wired to recording units on shore. Continuous records of the roll, pitch, and yaw of many vessels were taken during launching, together with the motion down the ways.

A series of model experiments has been conducted with a trawler model, in which the main factors affecting side launching were systematically varied. From this work a method has been developed, using design diagrams, to enable launching characteristics to be predicted in advance, with practical accuracy.

From author's summary

3588. Gawn, R. W. L., The Admiralty experiment works, Haslar, *Quart. Trans. Instn. nav. Arch. Lond.* **97,** 1, 1–35, Jan. 1955.

3589. De Groot, D., Resistance and propulsion of motorboats, *Inter. Shipbldg. Progress* **2,** 6, 61–80, 1955.